Marwell Preservation Trust
Sparsholt College, Hampshire
EAZA Research Group

Second European Zoo Nutrition Conference
6th – 9th April, 2001

Southampton, United Kingdom

ABSTRACT BOOK

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Peter Bircher

Foreword

In quiet contemplation, after a good meal and bottle of wine, I have often wondered if the rest of the animal kingdom also enjoys the food they eat or is eating just something carried out in response to hunger signals from the nervous system? Observations in the wild state suggest that many species are choosy about what they eat, carefully selecting fruits, leaves and plump insects at certain stages of development and/or on a seasonal basis. One assumes that taste has an influence in this selection process, but that other innate and learned factors must further influence the animal in order that a balanced diet is consumed. These factors must also serve to protect the animal from harmful food items, to the extent that animals released back in the wild state, even after several generations of captive breeding, still seem to avoid toxic items. We may never know if animals enjoy food like most humans do, but we do know that food remains the greatest influence in their daily lives.

There has always been a stark contrast between what an animal eats in the wild state and what is given to them in captivity. The formulation of many zoo-based diets has traditionally been influenced by the non-availability of natural food items, and by the ready availability of rations fed to their domestic or human counterparts. In many instances this has resulted in poor nutrition which has been directly linked to growth-related problems or the failure to breed and successful raise progeny. During the early stage of my zoo career, which now spans some thirty years, I can well remember asking some basic questions about the diets being fed in many of the major European zoos. I quickly realised that very little was known about the eating habits of animals in the wild and that captive diets where often formulated on the basis that 'if it eats it, then it must be OK'. Obesity was the most common outcome of such feeding practice.

In the past twenty years there has been a much greater interest shown by zoos world wide in trying to improve this situation. Some institutions can now even boast that they employ a qualified nutritionist on their staff and, better still, are involved in field research. Nutritional matters are often on the agenda of the many international meetings where health and welfare matters are the topics for discussion, and, in fact, there is now a wealth of information available to zoo personnel responsible for compiling diets. In addition, several large companies manufacture specialist diets for exotic animals.

Whilst the standard of zoo diets has undoubtedly improved in recent times, there still remain more questions unanswered, than those resolved. Many of these are associated with more complex problems like trying to determine if nutrients in diets are available to the animal, or the long-term effects of feeding artificial diets. However, with the possible exception of the rat, our knowledge of the dietary requirements of most species still leaves a great deal to be desired.

A major obstacle preventing the further advancement of good nutritional practice is the piecemeal way in which information is now disseminated.

On several occasions I have accidentally stumbled across valuable data, which, if known about previously, would have saved me much time and effort. Hence I have long been of the opinion that some sort of centralised database is needed with a formal Group appointed to administer it: with the advent of the Internet this should now be possible on a global basis.

I had very much hoped that this matter, and also the possible formation of a European Nutrition Group, would have been on the agenda of the Nutrition Conference to be held at Southampton during April 2001. Sadly, after some twelve months of planning, this conference was cancelled due to the outbreak of Foot & Mouth Disease in the United Kingdom and parts of mainland Europe. However, the conference organisers were able to hastily convene a special meeting at the Sparsholt Agricultural College, near Winchester. This meeting was called in order to discuss the dissemination of conference material, of which this abstract forms a part, and also to try and further some of the aforementioned issues – especially the formation of a European Nutrition Group.

The meeting concluded that there should be full publication of conference material and that the idea of Nutrition Group, possibly a part of the EAZA Research Group, e developed for a presentation at the EAZA meeting in Prague, September 2001. It was also pleasing to note that the 3rd Nutrition Conference, which will be held in Antwerp at the end of 2002, is currently in the early stages of planning.

Finally, I think I can now say with some degree of confidence that nutrition is beginning to receive the priority necessary in European Zoos. A great deal of effort is still needed, but, hopefully, we will now maintain the momentum generated by the 1st European Zoo Nutrition Meeting held at Rotterdam in 1999.

Peter Bircher, Marwell Zoological Park 28th August 2001

Contents[1]

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ADVANCING ZOO NUTRITION THROUGH GLOBAL SYNERGY

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Increasingly recognized as an essential foundation of sound animal management, health, and reproduction programs, comparative nutrition, as a scientific discipline, can realize expansive goals through integrated efforts to maximize Personnel, Communications, and Analytical resources. Indeed, the challenge for applying scientifically based animal management principles in the zoo profession globally, and recent mandates in animal welfare and inspection processes with respect to defined feeding programs, provide an exciting and timely catalyst for growth with almost unlimited potential. Over the past decade, both the American Zoo and Aquarium Association (AZA) as well as the European Association of Zoos and Aquariums (EAZA) have initiated nutrition disciplinary specialist groups, the Comparative Nutrition Society was formed, and the Conservation Breeding Specialist Group affirmed the value of a nutrition-based Working Group. Despite these umbrella organizations, the need for implementing nutrition programs at the local level is still apparent; fewer than 25% of US and European zoos employ nutritionists, with the percentage even lower elsewhere in the world. Globally, no specific academic programs, scientific disciplinary qualifications, nor licensure examination have been established which standardize training for a career as a zoo nutritionist, resulting in overlapping responsibilities that may be better served by another discipline such as food scientist or food service manager. As important as basic food handling and service aspects are in providing quality diets to zoo collection animals, specific training in biochemical evaluation of diets and comparative physiology provides a unique role for the zoo nutritionist. Many of the essential functions of safety and quality assessment, as well as provision of sound diets, can be met through Internet-shared communications that should be a priority of future focus. Maximal information exchange, with minimal duplication of effort, can be realized through the joint creation of accessible databases of Food Composition, Diet Evaluation, Nutrient Recommendations, Food Storage and Handling Protocols, Physiological Assessment Criteria, and a library of Bibliographic References. This trend has been initiated within The Netherlands through the adoption of a national standard diet assessment tool (Zootrition™) by the Dutch Federation of Zoos, and creation of national databases of food composition and diet registry. Overlap between the zoo nutrition specialist groups of AZA and EAZA are apparent at biannual meetings, training workshops, and through joint husbandry manual authorship. The Zoo Conservation Outreach Group and Toronto Zoo have led similar efforts within Latin American zoological facilities. WildPro®, an electronic encyclopedia of wildlife health and management, provides an example of integrated nutrition data in its web-based network for widespread global dissemination, and may be considered a primary resource for health professionals as well as the rehabiliation/reintroduction communities with which nutritionists need to interface. Linking information within an electronic framework also allows more rapid integration with other disciplines (i.e. reproduction, immune function, genetics) to advance the sciences. Finally, separate and apart from the resulting data, integrated analytical laboratory methodologies must be implemented to fill gaps in global databases, which most effectively meet the needs of the zoo nutrition community and provide accurate information on a timely basis.

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FEEDING PRACTICE IN CAPTIVE WILD RUMINANTS: PECULIARITIES IN THE NUTRITION OF BROWSERS/CONCENTRATE SELECTORS AND INTERMEDIATE FEEDERS. A REVIEW.

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We present a review on the feeding practice, the nutritional pathology and the documented nutritional peculiarities of zoo ruminants. Historically, the difference in chemical composition between browse and grass led to the conclusion that browsers need a diet lower in fibre and higher in protein than grazing ruminants. The term concentrate selectors", coined to describe browsing ruminants, additionally focused the attention on the chemical nature of a browser's diet assumed high in easily fermentable, soluble nutrients. In comparative nutritional surveys, browsing ruminants in zoos tend to consume less fibre, more protein and more nitrogen-free extracts than grazers. While this could be interpreted as a reflection of their nutritional needs, this feeding type displays, in comparative pathological surveys, a higher incidence of acidotic changes in the ruminal mucosa, indicating that this group does not ingest sufficient amounts of fibrous material. Additionally, data from controlled bilance trials does not support the notion that browsing ruminants have higher protein requirements. We suspect that the lesser fibre intake in browsers is due to their reluctance to ingest hay, the commonly used fibre source, which is usually offered *ad libitum*. Reluctance to ingest hay and digestive problems after hay ingestion have been reported for different browsing ruminant species. There is reason to believe that it is not only the chemical but also the physical difference between grass and browse that affected the evolution of different feeding types. Attention within the zoo community should focus on providing browsers with a fibre source that corresponds to the physical characteristics of their natural forage.

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COPPER DEFICIENCY IN YAK (*Bos grunniens*) AT WHIPSNADE WILD ANIMAL PARK

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Copper deficiency has been diagnosed or suspected in a number of ruminants at Whipsnade Wild Animal Park including bontebok (*Damaliscus dorcas*), European bison (*Bison bonasus*), wapiti (*Cervus elaphus*) and yak (*Bos grunniens*). Prior to 1992 the yak diet was supplemented with copper sulphate, but the inclusion rate was variable and never greater than 180mg copper per adult per day. Between 1992 and 1994 it became evident that the herd was still suffering from a range of conditions which may be associated with copper deficiency including chronic diarrhoea, poor body condition and dull coat. The copper concentration in blood samples taken from animals immobilised for clinical or management purposes in 1994 ranged from 0.8 to 3.3µmol/L (mean 1.8, n=10), well below the normal cattle range of 9 to 19µmol/L. The copper supplement was therefore increased to 720mg copper per adult per day (1.8g copper sulphate) starting in September 1994, and over the period 1995-97 blood copper concentrations rose steadily. In 1995 they ranged between 2.4 and 13.8µmol/L (mean 6.7, n=9), and in 1997 between 6.4 and 16.6µmol/L (mean 10.7, n=8). Over the same period the incidence of diarrhoea decreased and general body and coat condition improved. Also the herd size grew, possibly due to an increase in fertility and neonatal survival. Other factors which may have been involved in the improvement in the health of the herd were the importation of a new herd male in 1992, and an intensification of anthelminthic treatment over the same period.

Hair depigmentation appeared in the autumn of 1998 in ten calves born during that summer. They had blood copper concentrations of 0.8 to 5.0µmol/L (mean 2.8), two yearlings also had low concentrations (0.5 and 1.3µmol/L), but an adult female sampled at the same time had a value of 8.4µmol/L, just below the normal range. This suggested that the older animals were taking all of the copper-supplemented concentrate pellets before the calves gained access to feeding troughs. The calves were injected with 62.5mg copper heptonate (Cuvine, C-Vet) and no further clinical signs were seen.

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ZINC (ZN) STATUS IN RUMINANTS

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Zinc (Zn) belongs to the essential food components. It is part or activator of more than 200 enzymes. The effect of marginal Zn intake on growth, reproduction performance, quality of skin and hair, and life expectancy are well known. However, the diagnosis of the trace element status in living wild animals kept in zoos is difficult since, as a rule, only blood, hair, claws and excretions are available for this purpose. The capacity of indicating the trace element status of several tissues is element-specific. Therefore, not all of them are suited as indicator tissues for the trace element status. Furthermore, it must be taken into consideration that the indicating capacity of organ tissues in the case of deficiency can be different from that in the case of exposure. The investigation of these laws could not be carried out in endangered species of ruminants, but in farm animals. For that reason, organ tissues of different species of wild ruminants kept in captivity were obtained at necropsy, analysed and compared with datas of domestic and wild living ruminants. The wild ruminants which were kept in captivity came from the Zoological Society of San Diego and from the Zoo Leipzig. For comparison, organ tissues from wild living and domestic ruminants were obtained from different locations in the states of Germany and Northern California. After dry ashing of samples the Zn concentration were analyzed by atomic absorption spectroscopy (Jarrell Ash 850) or optical emission spectroscopy with inductively coupled plasma (Spectroflame D, Spectro Analytical Instruments). The Zn status of different ruminants depends on species, age and - due to the homeostatically regulation - to a lesser extent on Zn intake. The results are discussed and compared with the status of further elements which have an antagonistic effect on the Zn status. The Zn limit value of the indicator tissues for a sufficient Zn supply are given in the species of wild ruminants.

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INDIGENOUS BUSH AS ANIMAL FEED

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Game and cattle farming is very prominent in the northern semi-arid regions of South Africa. The average rainfall is 400 mm per year. Due to a few very dry seasons and poor beef prices many farmers incorporated game farming in their strategy to survive. Hunters from abroad pay prices that exceed carcass meat value by far. Unfortunately adequate compensation for carrying capacity of game species was generally not made and severe bush encroachment resulted due to mismanagement. However, encroachment bush itself is a natural source of prime food for herbivores. Herbicides are used to kill the encroachment bush but some of them have a long residual effect, also killing grass and desirable trees, some of which are hundreds of years old. Heavy downpours shortly after applications can wash chemicals into natural streams. Dead bushes had to be burnt resulting in rehabilitation taking five to seven years and thus proving to be very expensive. In 1995 an entrepreneur working in wildlife and ecological services implemented a survival strategy for this problem. Specifically designed motorised saws are used to cut off encroachment bush at ground level preventing sharp wooden spikes causing foot injuries. It also prevents high tannin levels in the plant compared to stress like chronic browsing or axing. The bush is shredded on site in a robust mill. The product is sun-dried, hammer-milled and fortified with carefully formulated natural supplements before it is pelletised. The final product, trade marked as BOSKOS (bush feed) contains 10% crude protein, maximum 35% fibre, minimum 2.5% fat and total digestible nutrients amount to 60%. BOSKOS is produced from *Acacia, Dichrostachus, Combretum* and *Grewia spp*. is now a staple diet in zoos, havens for endangered species, and especially as a winter grazing supplement in national parks and game reserves around the world. BOSKOS is a primary source product in its own right. It is therefore significantly different from most other commercially - produced animal feeds in that it is not a by-product of a manufacturing process. BOSKOS is also an excellent diet supplement for orphan animals and has been especially successful for animals reared to adulthood and re-introduced to the wild. Acacia is a natural diet for wild animals, rich in natural trace elements drawn from deep in the earth by the root systems and retained in the processing of the final product. Herbivores in captivity instinctively appear to recognise BOSKOS as a foodstuff that is natural to them.

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FEEDING BEHAVIOUR AND ECOLOGY OF BEARDED PIG (*Sus barbatus*) IN KAYAN MENTARANG NATIONAL PARK AND AT BERLIN ZOO

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The feeding ecology, particularly food and feeding site selectivity as well as possible influences of changes in food distribution and quality were studied both in a field project and in feeding trials at Berlin Zoo.

The aim of the study, within the framework of a large multi-centred project on feeding and ranging ecology of bearded pigs, is to identify possible factors that influence choice of food items, dependence of these factors from availability and the possible consequences for migration. Bearded pigs, among Suidae, are unusual in that they regularly migrate over long distances in large groups/herds. Factors governing these migrations have not yet been identified in detail, it is however assumed that food availability (fruit masting seasons, which are not annually predictable) plays a role.

In the field study, vegetation and landscape parameters, as wellas food items selected, were recorded from 9 feeding sites at the Kayan Mentarang National Park, East Kalimantan, together with the composition of vegetationand landscape feature in a ca. 30m and a 500m diameter.

In the zoo study, at Berlin Zoo, a group of bearded pigs was observed, and feeding trials performed to simulate changes in quality (nutritional contact, composition, size) and spatial distribution of food items. Influences of these changes on social behaviour and activity patterns are discussed not only in relation to field data but also with regard to enrichment.

We thank the management and staff of Berlin Zoo and Kayan Mentarang National Park for generous support.

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QUALITY AND DIGESTIBILITY OF WHITE RHINO FOOD (*Ceratotherium simum*): A COMPARISON OF FIELD AND EXPERIMENTAL STUDIES

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Within the framework of a study on behavioural ecology and resource use in white rhinos, a study on nutrition of both free-ranging and captive white rhinos was conducted. This project about the quality and digestibility of white rhino food comprises two parts. The **field study** was conducted on a private game farm in South Africa where a healthy population of 65 white rhinos lives in an area of 30 000 ha. By following the tracks of individual rhinos, together with an experienced game tracker, samples of grass were collected from feeding sites. The grass species were identified and an equivalent to the amount consumed by the individual was cut and collected. Owing to the mean retention time of ingesta we tracked the same animal two days later to get a faecal sample. Two grass and faecal samples from each of three males were collected by tracking them individually.

The second part of the project was an experimental study with a group of five white rhinos in the zoo of Erfurt in Germany. The rhinos (one male, four females) were fed with four different diets. Each diet was given for a period of 15 days in the following order: grass only, grass with pellets (Pachyderm supplementary diet from Mazuri Zoo Foods), hay only, and hay with pellets. Together with the pellets a certain amount of the marker Cr_2O_3 was fed to the animals. Samples of each diet were collected daily. Faecal samples were collected every morning during the last ten days of each 15-day period. These samples were then pooled for each of the four periods. During the study the captive animals' behaviour was observed using scan and focus sampling methods in order to analyse the potential influence of food quality on the activity and social behaviour.

The following parameters were determined in the food and faecal samples of both studies:
By **Weender** Analysis:

- dry matter, ash, crude protein, crude oil, crude fibre, nitrogen free extractions

Analysis of cell wall constituents by **Van Soest** detergent tests:

- total cell wall contents (NDF), lignocellulose fraction (ADF), lignin (ADL), hemicellulose (NDF-ADF), cellulose (ADF-ADL)
- various minerals (phosphorous, calcium, etc.)
- gross energy (calorimeter)
- Cr_2O_3

Digestibility: The apparent digestibility is defined as the difference between the nutrient intake and the nutrient output expressed as a percentage of the nutrient intake.

In this project it was generally not possible to collect the total forage intake or the total faecal output per animal. Owing to that it is necessary to determine the apparent digestibility indirectly with a marker. This marker must be a substance which passes the digestive tract without being changed or absorbed, e.g. lignin or chromic oxide. In this study the natural marker lignin – a part of all grasses – was used if only one type of food was given. In the two feeding periods with two different types of food (grass with pellets or hay with pellets) the double marker method with lignin and chromium oxide was used.

The aim of the project is to compare the results of the field study and the experimental feeding trial in order to evaluate similarities and differences of food quality and digestibility in detail. The results will help to improve the husbandry of captive rhinos.

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SEASONAL NUTRITIONAL COMPOSITION OF PRINCIPAL BROWSE SPECIES CONSUMED BY BLACK RHINOCEROS *Diceros bicornis* IN ZIMBABWE AND A COMPARISON WITH ANALYSIS OF BLACK RHINOCEROS DIET IN A UK ZOOLOGICAL PARK.

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Principal browse species consumed by black rhinoceros *Diceros bicornis* in Matusodona National Park were analysed as part of a habitat assessment and study aimed at understanding nutritional aspects of translocating animals within Zimbabwe. Information derived from this work emphasising seasonal variations in the nutritional composition of browse, which may be of interest to managers of captive *Diceros* is presented. Potential differences between wild and captive diet composition are highlighted by comparing browse analyses with the nutritional content of black rhino diet at a UK zoological park.

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PASSAGE RATE AND DIGESTION OF THE OKAPI *(Okapia johnstoni)*

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Feeding of many browsing ruminants still poses some challenge to the holding facilities. There is an ongoing discussion to what extent this type of ruminant is able to digest fiber. Digestibility depends on the time the food stays in the fermenting chambers of an animal. Although there has been already some research on okapi nutrition and digestive physiology, important data like passage rates are still lacking from this mid-sized browser. In this project nutritional data (passage rate; feed intake, digestibility) and ethological data (activity budget) were collected to get an extensive picture of okapi digestive physiology. As a preliminary report of this ongoing study, data on passage rates and related data are presented.

Passage rates of 2 adult male okapis (weight app. 200 and 240 kg) were measured. They were determined by using cobalt-EDTA as marker for the fluid phase and chromium mordanted fibers as particle phase marker (particle size of marker fibers <2 mm). Faecal samples for passage rates were collected over 10 days, the use of a time lapse video recorder allowed the determination of the exact time of faecal production during the night. Marker excretion curves and mean retention times (MRT) were calculated by assuming the formula of Grovum and Williams (1973) as a suitable model and by performing nonlinear regression of the measured marker concentrations. Titanium oxide (TiO_2) was used as a marker for faecal output.

Dry matter intake of the animals was 3,15 kg (animal A) and 3,90 kg (animal B) per day. Dry matter digestibility was 68% (A) and 71% (B), NDF-digestibility with 46% (A) and 48% (B) was rather low. Animal B consumed a diet with a higher proportion of grain based concentrate. Calculated mean retention times were 34,9 h (A) and 33,0 h (B) for the fluid phase and 48,6 h (A) and 46,6 h (B) for the particle phase. Selectivity factors of the whole gut (MRT particle phase / MRT fluid phase) were 1,39 (A) and 1,41 (B).

Reference:

Grovum, W. L.; Williams, V. J. (1973): Rate of passage of digesta in sheep. 4. Passage of marker through the alimentary tract and the biological relevance of rate-constants derived from the changes in concentration of marker in faeces. **British Journal of Nutrition** *30*, 313-329.

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A SURVEY AND DATABASE OF BROWSE USE IN BRITISH AND IRISH ZOOS

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Provision of browse has potential nutritional and behavioural benefits for many zoo animals species; for some it may even be an essential component of proper nutrition.
However, browse supply is often limited, particularly in city zoos and during winter in temperate regions. This limitation is often exacerbated by lack of knowledge of which types of browse are suitable for use with which animals and fear of toxic effects. This can result in zoos being restricted to only a very few browse species which are known to be safe.

To address this problem a database of browse use for mammals within Federation member zoos has been compiled by the Research Group and the Plant Group of the Federation of Zoological Gardens of Great Britain and Ireland. A questionnaire was sent to all member zoos to request information on which browse species they provide for which mammal species. Additional information such as restrictions on parts of the plant used, seasons when used, quantities used, any adverse effects resulting from use etc. was also requested.

A Microsoft Access database has been compiled with the information from this survey. It can be searched by plant or animal name and returns the number of zoos which have provided a particular plant for a particular mammal without any adverse effects. The database can also be searched for adverse effects and full information about every plant/animal/zoo combination can be accessed. The database does not make browse recommendations, but allows zoo staff to see how many other zoos use a particular plant species and for which mammals, and thus enables them to make better judgements as to its likely safety. The database holds approximately 2000 records and includes 113 different plant taxa. The average number of plant taxa used as browse in a zoo is 18, with a maximum of 42. Therefore, by reference to the database, all zoos should be able to considerably increase the range of browse species they use.

The database is available on CD-ROM from the Federation of Zoological Gardens of Great Britain and Ireland. Also included on the CD-ROM is a web-interactive directory of poison plant information combining all records from several web-based poisonous plants databases. This allows quick and easy access to all relevant toxicity information available for several hundred plant species. The CD will thus be an invaluable tool for all zoos needing to review their browse provision for mammals.

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BROWSE SILAGE IN ZOO NIMAL NUTRITION – FEEDING ENRICHMENT OF BROWSERS DURING WINTER

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A major challenge in zoo animal nutrition is the adequate feeding of browsers, such as certain antelopes, giraffes (*Giraffa camelopardalis*), moose (*Alces alces*) or black rhinos (*Diceros bicornis*). The supplementation of browse in these species has been recognised to constitute an important factor in the feeding of these species. Whereas in spring and summer it is fairly easy to provide adequate browse, during winter months when browse is scarce, diets of theses species may become unbalanced. As substitutes zoos may recur to feeding alternative feedstuffs such as apple pomace or may freeze browse during the summer months, which can be offered in the winter. However, these methods are cost and energy intensive and may require large storing capacities which often are not available.

A practical alternative is the production of browse silage, which is cheap and easy to produce. At Zurich Zoo this method has successfully been applied for five years. In late spring as much available browse as possible (diameter up to 3 cm) is processed in a chaffcutter. Subsequently the browse is tightly filled into plastic containers (Volume 200 l) which are closed airtight and stored at temperatures not higher than 20°C. No additives are added to the browse. Currently approximately 1200 kg of browse silage is produced annually with this method. From November onwards the silage is fed to four black rhinoceros (*Diceros bicornis*) on a daily basis.

Chemical analysis of the browse before and after silage process shows no significant alteration in composition (Table 1). The silage is very popular in black rhinoceros and represents an excellent enrichment of the diet. Furthermore it provides the animals with a variety of secondary plant compounds such as lignin or tannins which are naturally ingested by browsers in the wild and may contribute to their adequate digestion.

Table 1: Chemical analysis of browse (willow and maple) before and after silage process

		Before*	After*
Dry matter	%	47.8	46.8
Organic matter	%DM	96.4	96.2
Crude protein	% DM	4.9	5.3
Crude fat	% DM	1.0	1.3
Crude ash	% DM	3.6	3.8
Crude fibre	% DM	51.6	53.2
ADF	% DM	60.1	63.7
Lignin	% DM	14.7	16.6
Cellulose	% DM	45.4	47.1
Gross energy	MJ/kg DM	18.8	19.0
Calcium	%	0.9	0.9
Phosphorus	%	0.1	0.1

* Differences between data in columns are not significant

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FAT INTAKE AND APPARENT DIGESTIBILITY OF FIBRE IN HORSES AND PONIES

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Several experiments are done by the author in which horses or ponies were given extra fat in the form of soybean oil (Jansen, 2001). In all experiments apparent total tract digestibility of crude fibre declined. Similar reductions were seen for the digestibility of neutral and acid detergent fibre. The results of the experiments were pooled. In order to trace out other dietary components that could be related to fibre digestibility, a multiple regression analysis (Wilkinson, 1990) was performed with horses, experiments, periods and dietary crude fibre, crude protein, crude fat content as factors. By adding and deleting the factors the percentage of variance accounted for by the factors to the regression model could be analyzed. The factors fat content and experiment were statistically significant ($P<0.001$) in the model, when crude fibre or neutral and acid detergent fibre, hemicellulose and cellulose digestibility were chosen as the response variable. The factors horse, periods, crude fibre, crude protein and crude fat content were not statistically significant ($P > 0.10$).

The addition of 10 g fat per kg dry matter at the expense of an iso-energetic amount non-structural carbohydrates lowered the total tract digestibility of crude fibre by 1.0 percent unit (Table 1). Thus, for a high-fat diet, the digestible energy from components rich in crude fibre may be overestimated when calculating the energy content of the diet on the basis of feedstuff tables.

An increase of soybean oil by 10 g per kg DM increased apparent fat digestibility by 2.5 percent units (Table 1). An increase in fat intake will raise the amount of faecal fat of dietary origin and thus would lower the proportion of endogenous fat in the faeces. By comparing the low-fat diets without added soybean oil and the high-fat diets with soybean oil the digestibility of soybean oil could be estimated as 74.6 ± 14.9% (mean ± SD, n=42). This digestibility is about one fifth (20 percentage units) lower than used in the Dutch net energy system (CVB 2000). The net energy content of soybean oil would thus be overestimated with 5 MJ/ kg product. Other studies in which crude fat digestibility was measured show wide variation in the outcome. The results probably are related to macronutrients other than fat intake. This was the reason to subject the data on digestibility of crude fat digestibility to multiple regression (Wilkinson, 1990) with horse, experiment, period, crude fat, crude protein and crude fibre content as factors. The multiple regression showed that crude fibre content significantly ($P<0.0001$) diminished crude fat digestibility.

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DIETARY DETERMINATION OF MAMMALS AND BIRDS – A REVIEW OF TECHNIQUES AND APPLICATIONS

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The science of nutrition is a rapidly expanding field of zoo biology and the formulation of appropriate and scientifically based diets has become an integral part of the husbandry of many species. Yet for most free ranging mammals and birds information on their wild diets still remains unclear and often only the most generalised information exists. Even when information exists it frequently represents an approximation of the 'average' diet, ignoring the intricacies of habitat, seasonal, sex or even age specific variations.

Ecologically, an accurate knowledge of species' diets, and variations within them, contributes greatly to our understanding of biodiversity and competition between species. More critically, knowledge of accurate diets contributes to formulating strategies for wildlife conservation and management and allows husbandry to be specifically refined.

There are a variety of techniques that can be used to ascertain the diets of wild mammals and birds, from direct observation of items being eaten, or the identification of feeding remains through to digestive tract and faecal analysis. The limitations of such wildlife forensic work depend upon the level of diagnosis possible for a variety of feeding remains. In carnivores the identification of hair, feather, bone and invertebrate fragments can all yield information on items consumed whilst in herbivores plant cell fragments, seeds or pollen can be used to derive similar information.

The quantification of dietary information can be confusing and issues and considerations in understanding results will be discussed. For a number of techniques detailed captive studies have the potential to greatly refine and quantify analyses by allowing the correlation of information collected in the field.

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CARDIAC GLANDS WITH A DIFFERENCE - ELECTRON MICROSCOPY OF THE CARDIAC GLAND REGION OF THE BABIRUSA (*Babyrousa babyrussa*) STOMACH

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The stomach of the babirusa differs from that of other pigs in several aspects (Leus et al., 1999; Agungpriyono et al., 2000): it is larger and possesses a large *diverticulum ventriculi*, the gastric glands are confined to a small section at the end of the *corpus ventriculi*, the cardiac glands occupy a much larger surface area within the stomach (>70% *v*. ~30% in the domestic pig) and there are some variations in the distribution of endocrine cells. The pH in the lumen of the cardiac gland region was deemed suitable for the survival of the micro-organisms found therein. It was hypothesised that the babirusa is a non-ruminant foregut fermenting frugivore/concentrate selector (Leus et al., 1999). Previous studies of the stomach have concentrated on the gross anatomical and light microscopic structure, largely making use of museum material or specimens not collected immediately after death (Langer, 1973, 1988; Leus et al., 1999). In the mean time, we have been able to obtain stomach tissues from nine babirusa that were being euthanised for veterinary reasons not related to the gastro-intestinal tract. The quality of tissue fixation thereby permitted scanning and transmission electron microscopic investigations. Scanning electron microscopy revealed that the surface of the whole of the cardiac gland region was typically characterised by a honeycomb pattern. The entrance to each "honeycomb cell" had a diameter of approximately 0.06 mm. The walls of the honeycomb had a very granular appearance and extended into the stomach lumen a distance of about 0.2 mm in height above the glandular epithelium. At higher magnification the walls appeared to be almost entirely composed of a varied bacterial microflora. Light microscopy and transmission electron microscopy showed that at the luminal border of the cardiac gland epithelium, on top of the ridges between each glandular pit, non-glandular cellular tissue extended ribbon-like into the lumen. Sheets of squamous epithelial-like cells formed thin tube-like structures extending the lumen of the glandular pit. The surfaces of these sheets were covered by a dense layer of mixed gram negative and gram positive bacteria. No histological study of the babirusa stomach has yet drawn attention to anything like this honeycomb structure. No evidence of a similar structure could be found in the published histological studies of the domestic pig, other suids, or indeed the cardiac glands of the forestomach of other mammals. Further studies of fresh tissues of animals such as macropod marsupials, colobine monkeys, peccaries, camelids and sloths, which have larger areas of cardia or mucogenic glands in their stomachs, have been initiated to investigate the uniqueness of this honey comb structure. The latter's function also remains to be explored. Possible hypotheses include surface enlargement in order to increase attachment space and retention time of bacteria in a stomach without strong compartmentalisation and/or to increase the area for absorption of fermentation products. The explanation may have a direct consequence for the feeding requirements of babirusa in zoological gardens, which in turn, may be a key factor for the success of its conservation breeding program.

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Calculating energy requirements for zoo wildlife

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Research on diets of domestic and laboratory animals has provided diets suitable for the requirements of these animals. The diets for wildlife zoo animals are often extrapolated from domestic or laboratory diets of species closest to the wildlife species in question. This situation does not provide a satisfactory diet for wildlife zoo animals, which have a different purpose to, and are often in much more individual settings than, production animals. The resulting diet could affect the wildlife zoo animal's health and reproduction. For example, red deer and grey seals have been shown to produce more male than female offspring when the breeding females have abundant food resources and are in good bodily condition. Arabian oryx at Edinburgh Zoo produce predominantly male offspring, and their diet has since been estimated to be too energy rich for the species needs.

The present study addressed the problem for a range of wildlife zoo mammals by examining current models that predict basal metabolic rate (BMR). The value of an animal's BMR can be used to calculate the energy requirements of a diet.

Body mass is the most important characteristic of an individual. The best measure of the direct influence of body mass on BMR in mammals is found in groups of species that are physiologically and ecologically uniform. That is, BMR can be more accurately estimated when species are grouped by food habits than by order or class. Wildlife zoo animals represent not only a wide variety of foraging strategies, but within these are a number of different food types ingested. For instance, wildlife zoo carnivores include those that eat largely invertebrates. Wildlife zoo mammals in the present study were categorised for both body mass and food types.

In the present study, BMRs for a wide variety of wildlife zoo mammals representing a number of specific food habits was calculated. The results were then compared with current models. BMRs were generally lower than expected by the current models. The results indicated that zoo diets provided considerably more energy than required. A more accurate BMR value was achieved using the corrected model.

Results showed that large grazers and vertebrate eaters compared well with predictions from current models although corrected values were lower. For other categories of food habits, including arboreal frugivores and folivores, insectivores, terrestrial folivores and fossorials, the values of the current models were much greater in magnitude.

From the present study, it was concluded that the corrected method to quantify BMR was proved to be satisfactory through testing and provided a means to estimate energy requirement for wildlife zoo mammal diets. The companion paper will illustrate how these results can be used practically in calculating energy requirements and activity levels in the diets of wildlife zoo mammals.

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PRACTICAL USE OF ESTIMATING ENERGY REQUIREMENTS FOR CAPTIVE WILDLIFE

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There are many possible contributing factors to metabolic rate, many of which remain unknown. Emmans (1997) developed a generic equation for domestic mammals, based on basal metabolic rate (BMR) in domestic mammals. The equation expresses the rate at which an animal would produce heat from its own fat store at an arbitrary activity level in a thermoneutral environment. This clearly needs to be adjusted for practical use in wildlife species.

To obtain basic energy requirements for BMR, knowledge of the principal food type exploited by the species is necessary and an estimated weight. Physical activity is a major factor causing differences in the energy budget between zoo animals, as activity is variable among individuals and zoo collections. We demonstrate a simple method to provide this information. These three values are then simply entered into the equation, as we show with a range of worked examples.

Data were collected on the BMRs of exotic zoo species representating three major food habits, carnivory and large grazers and omnivores. In addition, average weights for a wide variety of species within these two food habits were collected. This allowed us to develop the original equation for each category to allow a more accurate value of BMR to be predicted for captive wildlife rather than domestic species.

We have investigated the activity budgets of representatives of the three food habits in our collection at Edinburgh Zoo. We obtained velocities to calculate the corresponding increase in metabolic rate for these individual animals. Observations were made on the individuals and the data were compared with a keeper survey. The results showed a significant correlation between methods. We were then able to categorise velocities into distinct levels for practical use.

The results of our study showed that the BMR provided by the Emmans equation can simply be corrected by a certain percentage related to the general activity level of an animal, the food habit and weight. The results provide energy requirement for maintenance at a given level for individual animals. Zoo animals are kept in groups and we discuss how to calculate this.

Ultimately, our simple recommendations estimate more precisely than previous methods the energy requirements for zoo animals. This allows feeding regimes to be optimised, thus improving the nutrition of captive species such as are found in zoo collections today. This paper illustrates, through worked examples for a variety of species, that this new method proves accurate and simple to use.

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MARKERS IN ZOO ANIMAL NUTRITION WITH SPECIAL EMPHASIS ON N-ALKANES

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Digestibility studies have traditionally been performed on live animals. Trials to measure digestibility *in vitro* have so far not been successful on a larger scale. This is one of the main reasons, why scientific digestibility studies in non-domestic animals and especially in zoo animals still are rare compared to domestic animals. Due to the fact that zoo animals are not tame they are more difficult to handle, controlled feeding and sampling are complicated and may even be dangerous.

Since total faecal collection, which is a reliable and commonly used technique in domestic animals, can only rarely be applied in zoo animals alternatives are have been looked for in the past. The increasing need for digestibility studies which are a prerequisite for the understanding of digestive strategies in zoo animals and hence are the basis for the correct feeding, has led to the search for alternatives to performe digestive studies in zoo animals. Inert marker systems have been found to be an important tool for such studies and they have been applied in several zoo animals. Markers may allow to measure digestibility, intake, faecal output, digesta kinetics and even diet composition, without the use of total faecal collection and individual caging. However the uncritical use of markers may also bear the source of important mistakes being made as to the interpretation of results. The present talk aims at presenting the frequently used internal (which are naturally present in feedstuffs) and external (which are mixed into the diet) marker systems used in zoo animal nutrition. Frequently used internal markers are: lignin, HCl-insoluble ash, manganese (Mn^{2+}). External markers are: chromic oxide (Cr_2O_3), mordants (Cr, Ce ect.), cobalt ethylenediamine tetra-acetic acid (Co-EDTA).

A new marker system in zoo animal nutrition, *n*-alkanes, is presented, which may be used both as internal and external marker. *N*-Alkanes, which are found in the epicuticular waxes of plants as mixtures of different carbon chain lengths, have received considerable attention in domestic animals in the last 15 years. A major advantage of the n-alkane technique is that it allows the estimation of digestibility and intake with the same marker system and therefore considerably reduces laboratory work. The *n*-alkanes have also been used as makers to estimate dietary proportions of different plant species or plant components Since different plant species tend to have differing mixtures of odd-chain alkanes (chain lengths in the range, 21 to 35 carbon atoms) diet composition can be estimated from the patterns of alkanes in the faeces and in the dietary components. Similarly, the dietary proportions of different component feedstuffs can be estimated by having them labelled with separate synthetic n-alkanes (usually even-chain).

Examples are given under which the different markers haven been used and their advantages and disadvantages will be discussed. Common mistakes connected with use of marker systems will be emphasized, such as the recovery of markers in faeces, analytical reliability, contamination and migration.

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THE EVALUATION OF A NEW DIGESTIVE MARKER SYSTEM IN REPTILES: *N*-ALKANES IN GALAPAGOS GIANT TORTOISES (*Geochelone nigra*)

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Digesta markers are used routinely to calculate faecal output and to estimate digestive kinetics. Marker systems, which have been used in reptiles, include water-insoluble dyes, coloured glass beads and vinyl discs, pieces of plastic tape, fluorescent powder, polyester strips and coloured tissue papers.
The kinetic behaviour of both liquid and particulate digesta phases in the gut, has only recently been investigated in reptiles. Cobalt ethylene-diamine tetra-acetic acid (Co-EDTA), ytterbium-marked particles and chromium-mordanted fibre were successfully used in tortoises (*Xerobates agassizii*). In the insectivorous six-lined racerunner (*Cnemidophorus sixlineatus*) the kinetics of water-soluble and lipid-soluble phases were studied with [14C]-polyethylene glycol and [3H]-glycerol triether respectively.

Most studies that estimated apparent digestibility in reptiles relied on total excreta collection. Chromic oxide (Cr_2O_3) has been used as an inert marker in green turtles (*Chelonia mydas*) and in American alligators (*Alligator mississipiensis*). Natural internal markers have also been used in reptiles: Acid-detergent lignin (ADL) was found to be an acceptable marker in two species of tortoises, and manganese (Mn^{2+}) has been used in a herbivorous lizard (*Sauromalus obesus*). Most marker systems, have been used in reptiles without thorough validation, which is a disadvantage for the comparison of the results obtained in different studies. A concentration on fewer marker systems would therefore be an important achievement. A marker system that could be of special interest under these circumstances are *n*-alkanes, carbon chains of different length, which are found in the epicuticular waxes of plants. Alkanes have received considerable attention in the last 15 years, for the study of different aspects of digestive strategies, such as digestibility, diet intake, food selection, and digesta kinetics in mammals, birds and fishes, and to estimate dietary proportions of different plant species or components in the diet of ruminants. A major advantage of the *n*-alkane technique is that it allows the estimation of different parameters with the same marker system and therefore considerably reduces laboratory work.

Two trials were carried out to validate the use of *n*-alkanes for the first time in a reptile species. Eleven Galapagos giant tortoises (*Geochelone nigra*) were used for estimating different parameters of their digestive physiology with the alkane method. Trial 1 was a kinetic study with determination of the mean retention time (MRT) in four adult and four juvenile tortoises. Estimates of digesta MRT obtained using *n*-alkanes were compared with those derived from the use of the respective liquid-phase and particulate-phase markers, Co-EDTA and Cr-mordanted fibre. In trial 2, diet composition, food intake and apparent digestibility were determined in two adult and seven juvenile tortoises. The results obtained with the alkane method were compared to values of observation and total faecal collection and to results of two traditional markers acid-insoluble ash (AIA) and acid-detergent lignin (ADL).

In conclusion the current study showed clearly that *n*-alkanes possess a great potential as markers in herbivorous reptiles, since they allow the estimation of different aspects of digestive physiology with one marker type only. The use of the alkane method in future studies will be discussed and examples given in the presentation.

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INTRODUCING ZOOTRITION IN THE NETHERLANDS: A JOINT APPROACH

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Rotterdam Zoo has used the program "Animal Nutritionist" (N-Squared Incorporated Computing, Silverton, Oregon) since 1988 for calculating zoo diets. In 1993 a project was initiated by the Dutch Federation of Zoos to introduce and implement use of Animal Nutritionist in all Dutch zoos. During that project a new Dutch feeds database was created and most of the diets were used by zoos were included. Through limited support by the N-Squared Incorporated Computing company and rapid advances in computer technology it became necessary to create a computer program much more sophisticated than originally envisioned, with the potential for new modules to be added as funding and information becomes available. The Wildlife Conservation Society's Department of Wildlife Nutrition took the initiative and developed a program called Zootrition that became available in 1999.

In reply to: the Netherlands the Nutrition Department of Rotterdam Zoo, in co-operation with Amsterdam and Emmen zoos, took the initiative to modify the program to meet the requirements of Dutch zoos, as had been done with Animal Nutritionist. The first stage was to establish a special Zoo Nutrition Project Group, with representatives from Dutch zoos, the Nutrition Department of the Veterinary Faculty of Utrecht and the Van 't Hall Institute of Leeuwarden. Students of the Van 't Hall Institute searched the literature for analyses of foodstuffs used in the Dutch zoos and in included them in a special database in Zootrition called 'Dutchzoo'. During the second stage all available zoo nutrition information, both scientific and so called 'grey' (anecdotal) literature, in Dutch zoos was studied. Relevant data was included in the requirement database of 'Dutchzoo'. In 2001 a project will be initiated to include all diets used in Dutch zoos in the 'Dutchzoo' database. In order to make the nutrition information accessible to other zoos, English is the standard language. Updates will be available regularly on CD-ROM for all Dutch and other zoos. Plans are in progress to also make this database accessible via a dedicated Zootrition web site.

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PRACTICAL APPLICATIONS OF ZOOTRITION AND CHANGING HOOFSTOCK DIETS

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Due to a lack of knowledge and alternative feeds, hoofstock in zoos have often been fed commercially available agricultural feeds designed for high production animals. In contrast to the goals of agricultural production, e.g. meat, milk or eggs, a zoo diet aims to provide correct nutrition to minimise the incidence of health problems and improve quality of life. Problems in zoo species associated with agricultural products include excess horn and hoof growth, kidney and liver problems, acidosis, obesity and pathological changes in ruminant guts.

In the past, it has been difficult to compare diets with requirements as it involved long, labour intensive calculations. However, with the advent of the Zootrition software program, it is now possible to evaluate nutritional quality of diets and compare with dietary nutrient recommendations from TAG nutrition advisors and sources such as research articles. This paper describes the steps involved in changing hoofstock diets to ones more suitable to exotic species, using an appropriate software program.

Ungulate diet

The animals and feed involved in the study were:

Species	***Pelleted Diet***	***Costs per Day(£)***
camels	Cattle Cobs	0.99
guanacos Arabian oryx Scimitar Horned oryx	Red Label dairy pellets	2.73
Western Grey kangaroos Bennet's wallabies	Diet A pellets	7.68

The diets were entered into the software program and compared with information on the requirements of exotic species. The inappropriateness of the diets became apparent. The agricultural pellets, containing an average protein content of 20%, were unsuitable for exotic species, which require Ca. 8 - 10% protein. The fibre levels in the agricultural pellets were on average 6%, whereas the requirements of exotic species can be up to 30% fibre.

Trial period for diet change

A new pellet designed for exotic ungulate species, 'Wildlife Nut', containing 8% protein and 25% fibre, as well as all the vitamins and minerals at appropriate levels was tested on the ungulates. A trial was carried out, which involved substituting small amounts of the old diet for the new pellet over 14 days, and monitoring consumption and health codes for body, coat and faeces condition.

Monitoring - health codes database

Keepers monitored animals and coded for health condition and pellet consumption daily. This ensured that if any animal were to suffer any ill effects due to the change of diet, it would be noticed quickly. The codes were entered into a database, which allowed easy analysis of the condition of the animals over the trial period. The new pellet was a success as the animals consumed them readily. Health codes over the period showed that there were no apparent adverse effects. The diet was then fully introduced and the animals continued to be coded weekly for faeces, body and coat condition, to monitor long term effects.

Costs

With many zoos being under a strict budget, the cost of animal feed is important. The cost of the diets before and after were compared using the software and the results showed that the new diet cost £6.49 in comparison with the old at £11.40 per day. A careful look using new software at existing diets can not only provide a healthier diet, but potentially cut costs also.

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PRACTICAL PROBLEMS OF COLLECTING DATA FOR NUTRITIONAL ANALYSIS: A STUDY OF ANIMAL DIETS AT BRISTOL ZOO GARDENS

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The purpose of an ongoing study at Bristol Zoo Gardens is to establish the nutritional content of the diets that are consumed by various species in the Zoo. Zootrition is a software package that can analyse diets if their constituents are known. If software such as Zootrition is to be of value to the Zoo community the data entered into it must be accurate. This paper outlines some of the many areas where inaccuracies occur, and suggests ways in which these problems can be reduced.

Food items are not widely referred to by their scientific names, which leads to confusion when searching the literature for nutritional analysis data and when using the Zootrition software. Once identified, the acquisition of accurate and detailed nutrient analysis for food items also presented a challenge, even for manufactured feeds. Of those contacted 75% of the suppliers of manufactured foodstuffs could not, or would not for commercial reasons, provide a detailed nutrient analysis of their product.

The diets offered and proportions consumed by 16 species have been recorded (6 birds, 10 mammals) and entered into the Zootrition software. Whilst the diet sheets kept on section are a useful reference, they are not a definitive guide for the following reasons:

- Food items are not listed as weights but arbitrary amounts e.g. two apples.
- Food items considered as enrichment tools are frequently overlooked.
- It was found that actual diets were determined predominantly by the keepers' interpretation of the diet sheets, and much variation occurred between keepers.
- All diets studied contained fresh foodstuffs and in all cases this component of the diet was subject to great variation, not only due to availability (both daily and seasonally) but also because variation is perceived as a form of enrichment.

Data collection techniques have been revised on several occasions and have largely been determined by the feeding behaviour of the species being studied. Ascertaining what is actually eaten is important:

- Many animals do not consume the entire food item – leaving peel, seed hulls etc. Therefore merely weighing remaining food items may give misleading results. For instance, because the nutritional content of orange peel and orange flesh are different, merely measuring what remains and analysing as 'orange' will not give accurate results.
- Food may be eaten by wild rodents and birds.
- The European Hamster creates food stores that, the study found, were not necessarily eaten at a later date.
- Animals fed on a mixed diet may feed selectively as this study noted in Toucan (*Toco toucana*) Hornbill (*Penelopides sp*) and Cockatoo (*Cacatua sp*). In this case it is necessary to identify the proportions of each component consumed. However, presenting these components separately affected feeding behaviour. One method that was adopted was to dry out the uneaten food to enable the components to be separated sufficiently.

The study of some diets presents more practical difficulties than others. Serious consideration must be given to such problems that, if not addressed, will lead to inaccurate data collection.

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FEED COMPOSITION AND DIGESTIVE CAPACITY IN PARROTS

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Nutrition in many species of parrots is based traditionally on seeds and feeds offered as mixtures (composition depends on species) and supplemented by fruits, vegetables and plants, eventually byproducts of animal origin (food like cheese etc.). Aim of several investigations on parrot nutrition performed during the last 10 years was the characterization of different ingredients by commonly used parameters of feed science.

Of special interest is the proportion of husk and kernel in seeds, the content of crude nutrients as well as of starch and sugar in the part of ingredients, that is actually ingested, i.e. the kernel. Furthermore the protein quality (content of amino acids), the mineral and vitamin contents as well as the palatability of various ingredients (for example in choose trials) were tested. Elder published data on the composition of seeds in toto (including their husks or shells) can often result in an incorrectly determining of the nutritive value of the really ingested part of the seed. Of importance in formulation complete diets for different species of parrots is the observation that some of preferred seeds and ingredients fed traditionally to parrots have sometimes a special pattern of amino acids (for example: peanuts and hemp: high content of arginine).

The mineral content of seeds used in parrot feeding can be characterized generally by low calcium concentrations (in kernels of starchy seeds: < 0.7 g Ca/kg dry matter[DM]; of fatty seeds: 0.9-3.6 g Ca/kg DM) and high phosphorus levels (in starchy seeds: 1.5-6.4 g P/kg DM, in fatty ones: 7-16 g P/kg DM), whereas the sodium content is low in general (0.1–0.6 g/kg DM).

Further studies were done to closer characterize supply of granivorous pet birds with β-carotene, tocopherols, thiamine, riboflavin and vitamin B-6. Evidently, β-carotene and riboflavin requirements of pet birds cannot be met by exclusive feeding seeds. Under certain feeding conditions (e.g. only few species of seeds are offered or birds develop a selective feeding behaviour) vitamin E and B-6 can be short in supply (without supplementation of the seed mixture). Only for thiamine, the relative high activity of analyzed seeds is expected to meet the animals` demand.

In recent studies the effect of crude fiber in the diet on digestibility of organic matter were tested in different species of pet birds (comparing to hens). Digestibility of organic matter of identical diets clearly revealed speciesspecific effects (love birds > cockatiels > budgerigars > canaries > hens > amazons). Eventually there are differences in the enzyme concentration within the intestinal contents or the species differences are based on anatomical conditions (size and proportion of the hindgut) and potential effects of intestinal microflora. Of special interest is the adaptation in enzyme secretion when the diet and fat or carbohydrate intake are changed as it was demonstrated in canaries and budgerigars.

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EXPERIMENTAL DATA ON FEEDING PELLETED/EXTRUDED DIETS IN PARROTS

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Since a few years feeding of pelleted/extruded diets to parrots is discussed controversially. Some bird fanciers dislike the use of these diets and put forward body weight losses of their parrots during conversion from usual seed mixtures to formulated diets. Furthermore a reduced time for feed intake is stated, that is linked with behaviour disorders (feather biting/picking due to boredom) and a reduced attrition of the beak. In spite of those reservations pelleted/extruded diets allow the composition of a well-balanced diet, that meets the requirement of the parrot in each stage of life. Furthermore a pelleted or extruded diet prevents the selection of individual ingredients within the offered feed (a.e. the choice of seeds like sunflower seeds, that are characterized by a high fat as well as energy content with the risk to obesity). Another aspect is the improved hygienic quality due to the common used ingredients (mostly based on cereals).

In feeding trials with amazons, grey parrots and cockatoos the parameters mentioned above were proofed. A comparison of the chemical composition shows great differences between formulated diets and commercial seed mixtures based on fatty seeds like sunflower seeds, safflower, hemp, pumkins, peanuts a.s.o. (see table 1). Compared to seed mixtures the pelleted/extruded diets are characterized by lower crude protein, crude fat, crude fiber and energy contents, but higher amounts of carbohydrates (formulated diets are based on maize, wheat and oat especially). In particular the calcium content of 10.9 g/kg dry matter in average indicates a high calcium supply. The calcium:phosphorus-ratio was well balanced. The sodium contents point to a supply, even if amounts of 1-2 g sodium per kg dry matter are not recommended.

Table 1: Chemical composition of pelleted/extruded diets compared to seed mixtures

data per kg dry matter	pelleted/extruded diets (n=16)	seed mixtures (n=10)*
crude protein (g)	196 ± 38.7	243 ± 63.6
crude fat (g)	81.6 ± 24.9	383 ± 125
crude fiber (g)	32.0 ± 14.0	38.2 ± 25.1
carbohydrates (g)	566 ± 56.4	284 ± 30.9
energy (MJ ME)	15.8 ± 0.60	21.4 ± 3.51
calcium (g)	10.9 ± 4.10	1.79 ± 1.24
phosphorus (g)	5.68 ± 1.26	9.08 ± 3.59
sodium (g)	3.21 ± 1.90	0.54 ± 0.24

*related to the ‘kernels’, that means the real intake after dehusking/shelling of the seeds

Conversion of parrots from usual seed mixtures to unknown formulated diets was done within a short time and without any problems (a.e. refusal of the diet combined with body weight losses). Offering seed mixtures ad libitum a typical rhythm of feed intake could be observed (higher ingesting activities in the early morning and in the afternoon), whereas formulated diets were ingested continuously during the whole day. The time spent for feed intake (measured in minutes per gram feed) did not differ significantly between pelleted/extruded diets and seed mixtures. When formulated diets were fed digestibility of organic matter varied between 76 and 84% (in comparison: ∅ 78% ingesting fatty seeds and ∅ 87% fed seeds rich in carbohydrates).

In general the results do not underline the reservations against formulated diets, but for a final estimation long time studies (a.e. of several years) are absolutely necessary.

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AVIAN EGG QUALITY CHANGES WITH INCREASING EGG PRODUCTION EFFORT[1]

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A female bird deposits all the chemical nutrients required for the growth of an avian embryo within a sealed unit over a short period of time. Variation in both the total amount of resources allocated to a clutch of eggs and the distribution of those resources within a clutch can have a profound influence on both her own and her offspring's fitness. There is good evidence in lesser black-backed gulls (*Larus fuscus*) of a trade-off between the number and the quality of eggs. By removing eggs as they were laid, the number of eggs produced by lesser black-backed gulls was experimentally increased beyond the normal clutch size of three, at the expense of chick viability. Neither hatching nor fledging success of the eggs was related to their fresh mass, but to their position in the laying sequence, suggesting that changes in egg composition had a substantial effect on offspring survival. The objective of this study was to examine the chemical composition of experimentally induced extended clutches in more detail, in order to elucidate which aspects of the eggs are involved in this trade-off.

Analysis of egg composition was performed for three eggs (first, third and last egg laid), from 12 extended clutches (all greater than three eggs). Analyses were performed at the Central Nutritional Laboratory (Pedigree Masterfoods) and composition factors measured were water, lipid, crude protein, ash, selected essential amino and fatty acids. Levels of total carotenoids and fat-soluble vitamins A and E were measured at the Scottish Agricultural College.

On average birds were able to produce three times the normal clutch size. Egg mass declined significantly over the laying sequence, but weight of the last laid egg did not fall below the weight of the last egg in a normal three-egg clutch. Eggs laid at the end of a sequence contain relatively less protein and lipid and relatively more water than earlier-laid eggs. On a finer scale, the weight of amino and fatty acids declined in absolute terms within an extended sequence, but relative to egg mass remained at the same concentration. This was not the case for vitamin E and total carotenoids. There was a highly significant decline in the levels of these compounds from first to third eggs and the decline appeared to plateau after the third egg, since there was no further significant decline between third and last laid eggs.

Smaller eggs contained most major nutrients in the same proportions as larger eggs, suggesting a blueprint for egg composition exists within the female, with limited scope for variation. That the last egg laid in extended clutches was not smaller than third eggs in normal clutches indicates the probability of a minimum size threshold below which an egg is unlikely to hatch and survive. Earlier laid eggs contained significantly greater quantities of vitamin E and carotenoids, a phenomenon also observed in normal three-egg clutches. Both compounds are powerful antioxidants that protect both against peroxidative damage during development and the oxidative stress associated with hatching.

While extended clutches are not a common natural occurrence, they demonstrate the extremes of egg production and how seriously an embryo may be compromised by very small changes in egg composition. However, it is possible to override this effect by means of supplementary feeding. Avian captive breeding programmes have utilised the practice of pulling eggs from a female to maximise reproductive effort in any one breeding season. Without due attention to the nutrition of the laying female, this practise may in fact negate the benefits of increased egg yield by producing eggs of poorer quality which either fail to hatch, result in weakened offspring or have a biased sex ratio.

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[1] Presented at the Third Comparative Nutrition Symposium, August 2000, Asilomar, California, USA

HANDFEEDING OF YOUNG PARROTS – TECHNIQUES, DIETS AND RECOMMENDATIONS

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In recent years handrearing of pet birds has become a standard procedure of breeding valuable pet birds (e.g. African greys). In this case nestlings are fed with a special powdered complete diet, mixed with water (a.e. 1st to 4th day of life: 1 part diet diluted with 6 parts water; 5th to 8th day of life: 1 part diet diluted with 4 parts of water; from the 9th day of life: 1 part of water : 2 parts of diet). This prepared solution is administered directly by a syringe into the crop during the first few days of life or afterwards into the beak by a teaspoon.

The labelled ingredients of commercial handrearing diets comprise only a few nutrient contents (i.g. crude protein or crude fat), whereas data on amino acids or minerals are frequently absent. Therefore this investigation should give among other things a quantitative idea of the energy and nutrient contents in commercial handrearing diets (n=11) in order to assess the suitability for rearing young pet birds.

	nutrient contents[1] of handrearing diets[2]			**necessary nutrient contents[3] for**	
nutrients	**x ± s**	**min.**	**max.**	**budgerigars**	**lovebirds**
crude protein	14.4 ± 1.82	12.4	17.8	9.54	8.90
lysine	0.735 ± 0.110	0.491	0.880	0.329	0.316
met + cys[4]	0.462 ± 0.184	0.234	0.695	0.469	0.368
arginine	0.729 ± 0.143	0.591	1.140	0.484	0.430
calcium	0.616 ± 0.243	0.349	1.145	0.276	0.271
phosphorus	0.312 ± 0.121	0.175	0.518	0.156	0.160
magnesium	0.086 ± 0.024	0.053	0.128	0.011	0.012
sodium	0.133 ± 0.095	0.049	0.356	0.028	0.036
potassium	0.346 ± 0.119	0.236	0.552	0.069	0.072

[1] g/MJ ME [2] MJ ME/kg dry matter: ∅ 15.2 ± 1.16 (min.: 13.0; max. 16.8); crude fat: 7.38 ± 1.10 g/MJ ME; starch: 29.5 ± 3.16 g/MJ ME; sugar: 2.48 ± 2.47 g/MJ ME; [3] derived from growth rates of youngs as well as the body composition (Kamphues *et al*. 1996); [4] methionine + cystine

A comparison of the analysed nutrient contents and the factorially derived necessary nutrient contents in handrearing diets for budgerigars and lovebirds shows sufficient crude protein, lysine and arginine contents. On the other hand some of the products showed a lack of the sulphureous containing amino acids methionine and cystine (feather growth ↓). All minerals met the requirements of the youngs, but some mineral concentrations were higher than needed (i.g. high calcium contents → possible interactions with copper or zinc; high sodium contents among a limited water intake). Furthermore some of the handrearing diets contain an excessive high content of vitamin A (up to 47,000 IE/kg diet).

In general the results verify, that on the one hand the requirements of sulphureous amino acids for feather growth in nestlings are frequently underestimated and that on the other hand the calcium requirements (mineralisation of skeleton) is often overestimated. Probably the primarily problem of handrearing in pet birds is not caused by insufficient energy and nutrient contents of the diets, but to the consistency of the suspended diets within the gastrointestinal tract (i.g. stasis of the crop content).

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Kamphues, J., N. Rabehl and P. Wolf (1996): Derivation of necessary nutrient concentrations related to energy content in diets for growing pet birds (canaries, budgerigars, lovebirds). **Proc. of the European Society of Veterinary and Comparative Nutrition**, Veldhoven, 12.9.1996, 29-30.

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A PRELIMINARY ASSESSMENT OF CIRCULATING CAROTENOIDS AND MINERAL VALUES OF THE PUERTO RICAN PARROT (*Amazona vittata*) MAINTAINED IN CAPTIVITY, WITH IMPLICATIONS FOR ITS HEALTH AND FERTILITY

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In order to identify any differences in sera chemistry that may be linked to reproductive success, blood samples were evaluated from the Puerto Rican Parrot (*Amazona vittata*; N=26) and the Hispaniolan Parrot (*Amazona ventralis*; N=11) maintained in captivity at two sites on the island of Puerto Rico. Circulating carotenoids and minerals were assessed and compared among various breeding categories. Significant differences were detected for Ca:P ratios for the Puerto Rican Parrot and the Hispaniolan Parrot when compared to published values for other psittacines, with phosphorus values all exceeding 8.7 mmol/L in the former two species. Calcium values were lowest in the infertile Puerto Rican Parrots ($\bar{x}$ = 1.25mmol/L) but due to the small sample size, these results are not conclusive. Iron levels in infertile Puerto Rican Parrots ($\bar{x}$ = 60.89 µmol/L) were all higher than those for poultry (28.66-53.73 µmol/L) while values for other breeding categories ($\bar{x}$ = 35.6 µmol/L) were within the lower range for poultry. Sodium values were higher in most Puerto Rican ($\bar{x}$ = 166.06 mmol/L) and Hispaniolan Parrots ($\bar{x}$ = 172.29) when compared to both poultry (122-162 mmol/L) and other captive psittacines (134-158 mmol/L), with highest values detected in infertile Puerto Rican Parrots ($\bar{x}$ = 180.96 mmol/L). Zinc values were low for both Puerto Rican ($\bar{x}$ = 27.64) and Hispaniolan Parrots ($\bar{x}$ = 17.37), mainly falling below the minimum normal value for poultry of 28 µmol/L. Total carotenoid values for the Puerto Rican Parrot ($\bar{x}$ = 679.12 µg/dL) were nearly double those of the Hispaniolan Parrot (353.43 µg/dL). No β-carotene was detected in any of the samples and, due to the large intraspecific variation, no statistically significant differences were detected in values for either retinol ($\bar{x}$ = 91µg/dL) or vitamin A palmitate ($\bar{x}$ = 31 µg/dL). Values for α-tocopherol were significantly lower in infertile Puerto Rican Parrots (0.65mg/dL) when compared to fertile or infertile Hispaniolan Parrots (2.21mg/dL) and, even though differences were detected among other breeding categories, these were not statistically significant. Little variation was observed with α-tocopherol either among groups or between species. The higher iron and lower α-tocopherol values may have dietary implications for the higher infertility in the Puerto Rican Parrot and the higher sodium values for both the Puerto Rican Parrot and the Hispaniolan Parrot may require further investigation.

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CAROTENOID UTILISATION IN WILD ANIMALS: IMPLICATIONS FOR ZOO NUTRITION

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Carotenoids are a diverse group of more than 600 lipid-soluble hydrocarbons that animals obtain in the diet. Since carotenoids are widely responsible for the pigmentation of integument in birds and fish, it is common practice to supplement the diets of certain species in zoos with carotenoids to achieve a visual appearance that seems species-typical. But studies of wild animals indicate that carotenoids have profound effects on reproductive success both directly and indirectly. For example, females prefer to mate with the most brightly pigmented males, and parents preferentially feed chicks with brighter gapes. It has been suggested that such signals have evolved as honest indicators of foraging efficiency, or health (because debilitation with gut parasitism can impair the assimilation of dietary carotenoids, and immune system or antioxidant activity can diminish the pool of body carotenoids). Carotenoids are also the reason why egg yolk is yellow. In a series of supplemental feeding experiments in wild lesser black-backed gulls (*Larus fuscus*), I have found that dietary carotenoids are subject to mechanisms of physiological discrimination, yolk is not maximally enriched with carotenoids under natural feeding conditions, and females with the dullest integument pigmentation are least able to sustain the level at which carotenoids are deposited through the clutch. Carotenoid-rich eggs have higher antioxidant activity and give rise to chicks with enhanced immune function. In light of these findings, dietary supplementation with carotenoids would seem a promising tactic to attempt to enhance reproductive success in zoo animals. But to that end more research is needed to identify phylogenetic and ecogenetic patterns in species requirements for individual carotenoids.

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FISH AND IRON STORAGE

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Introduction

Iron is an essential element in fish nutrition, but it can also act as a potent toxin. Iron accumulates when uptake exceeds utilisation and excretion. Iron overload can be primary, for example genetic disorders or adaptation, and secondary as a result of a high dietary iron content. In a dietary iron overload, iron is initially visible in the hepatocytes, later in the macrophages. The purpose of this study is to find out if fish show iron storage, what the iron contents is of commercial fish food, and at what iron level in the diet Koi carps (*Cyprinus carpio*) start loading iron in the liver.

Material and Methods

In a retrospective study, liver tissue of 130 fishes, presented the last 5 years for necropsy at the Diagnostic Service of the Dept Veterinary Pathology, Utrecht University, were analysed. The paraffin embedded liver tissues were re-cut in 5 :m slides, and were stained with Haematoxylin and Eosin (HE) and with Prussian Blue (PB) for iron. These livers were microscopically evaluated and the amount of iron in the liver was scored semi-quantitative from zero to four, according to the staining intensity and the number of cells affected. Hepatocytes and macrophages were scored separately. Eight commercially available fish foods, especially for carps, were analysed by the Weende-analysis and Flame Atomic Absorption Spectrometry (FAAS) was used for iron determination. A feeding study was done using Koi carps. All the Koi were about 15 cm and 45 gram. Four groups of 9 Koi's were housed in separate tanks at a water-temperature 18^{o}C. After acclimatisation for 3 weeks on a food with 50 mg/kg iron, each group of Koi's were fed for 6 weeks *ad-lib* with diets containing different amounts of iron (0, 150, 300 and 600 mg/kg iron). After six weeks, the livers will be evaluated as well by histology as by FAAS. Weekly water-samples will also be analysed.

Results

The first part of this study showed that 44 out of 130 (=33.8%) livers were positive for iron. The iron was present in the hepatocytes only (14.6%), in hepatocytes and macrophages (13.8%) and only in macrophages (5.4%). The average iron level in the eight commercial foods was 243 mg/kg Fe, (range 155 to 324 mg/kg Fe). The iron requirement recommended by the National Research Council (NRC 1993) in carp nutrition is 150 mg/kg. Fresh livers of 23 carps were collected at the beginning of the food study and analysed with FAAS for the iron contents. The average level was 259 :g/g liver (SD +/- 88, range 151 – 438 :g/g liver). The results of the feeding study will be presented.

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MEASURING UVB AND VITAMIN D LEVELS IN KOMODO DRAGONS

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Komodo dragons (*Varanus komodoensis*) are rare animals that only inhabit the islands of Komodo, Rintja, Padar and Flores in Indonesia. Currently only a few western zoos have these reptiles in their collection and unfortunately breeding results are poor in captivity. To date komodo dragons have only been bred in a few institutions. In 1992 and 1995 Rotterdam zoo received two adult komodo dragons from Singapore zoo and Surabaya zoo, but both died, in 1996 and 1998 respectively. In 1995 Rotterdam obtained 3 juvenile komodo dragons born at the National Zoo in 1994. From the literature it is known that juvenile komodo dragons in particular can suffer long bone fractures due to inadequate vitamin D synthesis through lack of UV-B light. Although the juvenile komodo dragons were exposed to UV-B in Washington they did not receive it in Rotterdam.

There are two sources from which vitamin D_3 (cholecalciferol) is provided normally: it is produced in the skin or it is absorbed by the diet. Vitamin D_2 (ergocalciferol) is derived from plant sterols. In the skin 7-dehydrocholesterol is photochemically (using UV-B) converted to provitamin D_3, then it isomerizes to vitamin D_3. Vitamin D_3 from the skin is bound to vitamin D binding protein which goes to the liver to be hydroxylated at the carbon 25 position by the enzyme 25-hydroxylase to form 25-hydroxyvitamin D_3 (25-(OH)D_3). Finally, in the proximal tubules of the kidney, the biologically most active metabolite: 1,25-dihydroxyvitamin D_3 (1,25-$(OH)_2D_3$) is formed. In nature the 25-OH-D_3 level in komodo dragons ranges from 150-200 nmol/l serum. After 19 months in the collection at Rotterdam, the blood values found in the juveniles of Rotterdam dropped to 18-31 nmol/l without adding extra vitamin D to the diet and without exposing them to UV-B. Supplying 450 IU vitamin D_3 /kg food (calculated) did not show any marked effect: after 2 months the 25-OH-D_3 levels ranged from 26 –37 nmol/l. One of the juveniles went to Gran Canaria (Spain) and within 9 months the 25-OH-D_3 level rose to 272 nmol/l. The other two juvenile Komodo dragons stayed in Rotterdam and obtained UV-B light. After 4 months the level of 25-OH-D_3 had risen to 201 nmol/l and exposure for 12 months maintained this level (195 nmol/l). During the whole period the quantity of $1,25(OH)_2D_3$ did not change significantly; this is in contradiction to 25-(OH)D_3 which over the whole test period varied from 121.6 to 235.3 nmol/ml. Compared with humans, the circulating 25-(OH)D_3 levels found in Komodo dragons in captivity are low, but the 1,25-$(OH)_2D_3$ levels are elevated. The assays used to measure vitamin D showed cross-reactivity between the comparable metabolites of vitamin D_3 and vitamin D_2. However, it is unlikely that the compounds measured are vitamin D_2 compounds, as Komodo dragons only eat whole prey and so despite cross-reactivity, it is unlikely D_2 compounds are changing. The current study shows that Komodo dragons respond to UV-B with a strong increase in circulating 25-(OH)D_3. However, the increase is not paralleled by a comparable increase in serum 1,25-$(OH)_2D_3$ levels. These levels did not change after UV-B treatment. This can be interpreted as a mechanism against life-threatening hypercalcemia, a consequence of elevated 1,25-$(OH)_2D_3$ levels and a defence similar to that found in humans. The 25-(OH)D_3 levels varies throughout the year depending on the season or sun exposure, however the serum 1,25-$(OH)_2D_3$ level does not show a comparable seasonal fluctuation but is steady throughout the year. Therefore, based on the data presented, it is questionable to conclude that Komodo dragons held in captivity without additional UV-B treatment actually suffer from vitamin D deficiency.

Finally, in order to routinely check the intensity of UV-B radiation from the lamps it is necessary to have a measuring device which is portable and small, and which is sensitive to the UV-B wavelength. To achieve this we designed and constructed an intensity meter which is sensitive to a narrow wavelength (10.17 nm at FWHM) around 302.01 nm.

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RATION MODELLING FOR GROWING OSTRICHES (*Struthio camelus*)

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In comparison to most husbandry animals, nutritional requirements of ostriches *(Struthio camelus*) have been scarcely investigated. Because of the time and finance consuming character of metabolism trials, an alternative method is suggested to come to adequate feeding of growing ostriches. As the digestive system of ostriches shows analogies to the equine digestive system, a computer model was built to predict energy and protein requirements for ostriches, based on two data sets : 1) the VEP/VREp system, a protein and energy evaluation system for horses developed by the Centraal Veevoederbureau in the Netherlands (4) and 2) the experimentally obtained true metabolisable energy values for ostriches (TMEo) from South-African research (1,2,3).

These already available TMEo values were used to calibrate the VEP values for a wide range of feedstuffs by linear regression fitting. The energy requirement, protein requirement and dry matter intake were estimated through body weight and growth rate, based on the formulae from several studies (5,6,7) respectively. The model was constructed in Microsoft Excel.

To test the model, two groups of 50 ostriches of similar origin were chosen in a way that they both had a similar variation in age (162-232 d) and initial body weight (19-73 kg). The first group received a high-fibre diet and the second group received a low-fibre diet. The growth rates, feed intakes and feed conversion ratios were used to calibrate the model.

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A COMPARISON BETWEEN THE NUTRITIONAL CONTENT OF DIETS OFFERED AND DIETS EATEN BY MINDANAO BLEEDING HEART DOVES *(Gallicolumba criniger)* AND SUPERB FRUIT DOVES (*Ptilinopus superbus)* AT BRISTOL ZOO GARDENS

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When presented with a mixed diet, birds will preferentially select certain components. It is therefore inappropriate to assess the nutritional content of diets offered to the bird, with the assumption that all of the nutrients are ingested in those proportions. The effect of this selection process on the diet consumed, and therefore the nutrients eaten, will depend on how selective the species is. This study used Zootrition to compare the nutritional content of diets offered and diets eaten by Mindanao bleeding heart doves *(Gallicolumba criniger)* and superb fruit doves (*Ptilinopus superbus)* at Bristol Zoo Gardens. The nutrients present in both the offered diet and the eaten diet were compared to recommended nutrient requirements for domestic pigeons[2], the closest species for which nutrient requirements have been suggested. Nutrients containing missing values were ignored, resulting in the analysis of only 14 of a possible 55 nutrients present in the Zootrition software.

These two species are fed the same diet, yet they showed a marked difference in their selectivity for the components of that diet. The superb fruit doves displayed strong preferences for dried fruit and apple. Although they only ate 59% (by weight) of the total diet offered, they ate 98% of the dried fruit offered and 86% of the apple offered. This strong selective behaviour resulted in the composition of the eaten diet to differ greatly from that of the offered diet, reducing the proportion of insectivorous mixes from 10% to 2% of the diet and completely eliminating Mazuri Sea Duck from the diet.

Differences in the composition of the food offered and the food eaten by the Mindanao bleeding heart doves were less marked than for the Superb fruit dove. This apparently low level of selection still produced large differences in nutrient composition between the diet eaten and the diet offered. In the eaten diet the proportion of dried mixed fruit was reduced by a third (by weight) whereas the proportion of mixed pulses was doubled.

For both species, the change in composition of the diet as a result of selection caused the proportion of nutrients eaten to differ from the proportion offered. The selective behaviour of the superb fruit dove lowered the proportions of crude protein and crude fat in the diet by about 30%. Interestingly, in the diet eaten by the Mindanao bleeding heart the opposite occurred. The proportion of crude protein was increased by one third, and the proportion of crude fat was increased by almost two thirds.

The levels of the nutrients offered and the nutrients eaten by both species did not match those recommended. The health of both species and in particular, the breeding success of the Mindanao Bleeding Hearts, suggests that the nutrient recommendations for domestic pigeons is not an accurate representation of the nutrient requirements of these two species. Alternatively, an exact match to the required nutrients may not be necessary for health or successful breeding.

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DIET SELECTION BY THE WHITE-NAPED PHEASANT PIGEON *Otidiphaps nobilis aruensis* AT THE BARCELONA ZOO.

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Otidiphaps nobilis aruensis is an endemic columbiforme from Aru Isle (South-West of New Guinea). It is poorly represented in captivity and there is not enough information known about the biology and wild status of this endangered specie. However, due to its insular situation, its wild status may be critical.

The Barcelona Zoo holds 18 individuals (53 %) of the total European captive population, with two wild caught breeding pairs. The aim of this study was to determine the diet consumed by the captive population of these birds at the Barcelona Zoo, and some of the factors that could have an influence on diet selection.

The study was carried on at the Barcelona Zoo with 11 (8.3) captive born individuals (descendants from the two breeding pairs), between 5 and 20 months of age at the time of study. The animals were housed individually and the intake was evaluated through three experimental periods (see Marques *et al*., 2000 for further details on housing and methodology). The diet consisted on 10 ingredients grouped in 4 categories: grains (wheat, millet and canary seed), commercial feeds (Zeigler Fruguivore Supplement, Universal Insectivorous Diet – Witte Molen, Egg rearing Food With Hedgerow Plants – Kasper Faunafoods), animal protein (mealworms, hard boiled egg), and vegetables (lettuce and fruit mix: apple, pear, banana, carrot). All ingredients were offered close to add libitum, except for the mealworms (*Zophoba* sp.), which were used to encourage birds to go on a weighing scale. The animals on this diet kept growing normally and looked healthy. The data obtained were analyzed by Proc Tabulate and Proc Mixed of SAS.

The animals consumed a total of 33,2 ± 0,82 g of diet (22 ± 1,30 g on a dry matter basis, DMB). This amount was 4 times lower than the offered. Great differences among individuals were observed on diet selection, but the mean diet composition was: 38 % grains, 25 % commercial foods, 19 % animal protein, and 18 % vegetables. None of the ingredients was consumed more that 40 % of the amount offered, except for the mealworms.

There were significant differences on ingredient selection among ages (juveniles 20 – 35 weeks old, n=7; elders 43 – 82 weeks old, n=4). The younger animals consumed significantly less grains than the older animals (10,3 ± 1,27 g *vs*. 17,2 ± 2,27 g; P<0,001). The younger animals, had instead, a tendency to eat more commercial foods (P=0,07). Additionally, some differences were observed among individuals that came from different progenitors in the consumption of some grains (i.e. wheat and canary seed). Whereas no differences in any of the other ingredient groups was detected. Curiously, males consumed significantly more lettuce than females (1,67 ± 0,5 g *vs*. 0,56 ± 0,5 g; P<0,01).

This project has been granted by the Durrell Wildlife Conservation Trust.

Reference:

Marquès H., Gonzalo C., Navidad G., Colom, L. (2000). Study of the diet fed to captive white-naped pheasant pigeons (*Otidiphaps nobilis aruensis*) at the Barcelona Zoo. ***Proc. Comp. Nutr. Soc.*** pp 132-137.

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ASSESSING DIETS FOR CONGO PEAFOWL *Afdropavo congensis* AT JERSEY ZOO

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Nutrition is a crucial aspect of the conservation of endangered species as it has direct consequences for the successful maintenance and breeding of species in captivity. Congo peafowl, *Afropavo congensis*, are considered vulnerable in the wild and there is managed captive breeding programme (EEP). However, the birds suffer from health and breeding problems in captivity. Chick mortality is high, resulting in low population growth. Causes of adult death (n=15) and disorders identified at post mortem in Congo peafowl at Jersey Zoo (1998-2000) included several which may be diet-related: obstruction of the oviduct caused by egg retention, egg peritonitis, kidney failure, heart failure, fat accumulation around the heart, hyperlipaemia, liver disease, lipidosis, gout and myocardial degeneration. This study was undertaken in order to calculate the nutrient composition of the diets provided to and consumed by the peafowl in order to evaluate the quality of the diet.

The diets provided to Congo peafowl (n=11) consisted of chopped fruits, sprinkled with the vitamin and mineral supplement Nutrobal, and a dry mixture containing pheasant breeder pellets, cracked corn, universal insectivorous mix, bread crumbs, carrot, and egg. Mealworms were also provided daily.

The diet was quantified over 10 days by weighing the amounts of food provided and left over per aviary (n=5), allowing calculation of the amount consumed per aviary, per individual and per kilogram body mass. As chopped fruit items were presented as a mixture, the remains could not feasibly be separated for individual weighing, so the birds were assumed not to be selective when consuming food. Control feeds were used to correct the feed remains for weight changes due to water loss or gain.

The dietary management software Zootrition (Wildlife Conservation Society, 1999) was used to analyse the nutritional composition of the diet, which was then compared to the nutrient requirement levels of pheasants *Phasianus colchicus*.

The peafowl showed a preference for the dry food over the fruit mixture. The most important imbalances in the diet were insufficient calcium and elevated fat levels, which have been linked to egg retention and fat accumulation respectively. The diets consumed contained inadequate amounts of protein when compared to the breeding requirements of pheasants, although the protein levels were adequate for a maintenance diet. A few difficulties in interpreting results arose from the lack of data in the nutritional breakdown of some food items.

New diets were formulated for both breeding and maintenance periods, to try to rectify some of the inadequacies. It is desirable for captive diets to vary with season, as they do in the wild. However, Congo peafowl appear to breed year-round at Jersey Zoo, which makes it difficult to define specific breeding and maintenance periods. Although the required nutrients and seasonal patterns are likely to vary between Congo peafowl and the temperate pheasant model, this analysis is still a valuable tool in assessing diets to ensure the provision of well balanced diets to maintain healthy birds in captivity.

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A COMPARATIVE STUDY OF IRON ABSORPTION IN MYNAH BIRDS, DOVES AND RATS[1]

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Aims
To compare the three steps of iron absorption, uptake, transfer and retention after a single dose application in different species fed on two levels of dietary iron.

Materials and methods
The animals consisted of 12 rats (*Rattus norvegicus*), 12 doves (*Streptopelia d. decaocto)* and 12 mynahs (*Acridotheres t. tristis* and *Gracula r. religiosa).* They were fed pellets containing low and high levels of iron (low iron diet (LID): 90 ppm iron, and high iron diet (HID): 570 ppm iron) for at least 2 weeks. The absorption and retention of iron from an oral test dose of 50 mg Fe (labeled with markers 59Fe and 51Cr) was measured using the whole-body gamma counter. Measurements were conducted on days 1, 2, 4, 7 and 14.

Results
Differences within and between species were determined for mucosal uptake, transfer and retention. Mynahs had the highest retention values among the studied species (48% for LID and 23% for HID). The results were significantly different ($P < 0.02$) within species for the two dietary groups, and among the other two studied species (34% -LID and 17% -HID in the rats, and 12% -LID and 3% -HID in the doves).

Conclusion
Mynahs have higher uptake and retention of iron when compared to rats and doves. All studied species have a regulatory mechanism for iron absorption but this mechanism seems much less effective in mynahs. When doves are considered as the reference species, based on our findings, the rats would normally need 26-41 ppm, and mynahs 19-25 ppm of iron in the diet.

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[1] Presented at the 18th Meeting of the ESVP, September 19-22, 2000. Amsterdam (NL)

THE ROLE OF SEASONALITY IN THE DIET OF RODENTS

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For many species of rodent the recorded diets in the wild comprise a wide range of food items. This is often interpreted as being an indication of their generalist nature and this may be true of a number of species, especially ubiquitous pests such as Western House Mouse (*Mus domesticus*) or Brown Rat (*Rattus norvegicus*), which are able to simultaneously utilise a variety of foods in a single habitat. However for many other species the broad range of items consumed actually represents a changing sequence of diet through the year and a corresponding sequence of specialist foraging behaviour. Thus the species should perhaps be viewed as highly adaptable and changing specialists rather than non-specialised generalists.

The reasons for this sequential specialisation through the year are still poorly understood for many species. For some this seasonally changing specialisation may be as a direct consequence of changing resources and an enforced response to a constantly varying habitat. For others though, evidence suggests that the sequential changing represents an active shift in diet initiated by the animals themselves.

This active shift may well be important in influencing or cueing a number of events in the annual cycle of such species, particularly reproduction and hibernation. A number of plant compounds have been proven to influence reproductive success in rodents or provide threshold levels which have to reached in order for reproduction to commence. Thus the feeding of appropriate food items at specific times of the year in captivity may well be important in maintaining normal annual and reproductive cycles in some species.

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DIET AND NUTRITION OF PIED TAMARINS *Saguinus bicolor bicolor* AT JERSEY ZOO

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The pied tamarin, *Saguinus bicolor bicolor*, is considered to be the most threatened Amazonian primate because of its restricted range in the wild. This makes the captive population an important safety-net, although there have been difficulties with breeding and maintaining them in captivity. Pied tamarins at Jersey Zoo and elsewhere have suffered from low infant survival, premature and stillbirths, chronic diarrhoea, "wasting marmoset syndrome" and metabolic bone disorders. These problems may be linked in part to diet, so a nutritional study was carried out at Jersey Zoo (which holds the bulk of the EEP population) in order to investigate whether the tamarins are being provided with, and are consuming, a diet with the correct balance of nutrients.

In the wild, pied tamarins consume insects, fruit and plant exudates. They are known to have high protein and vitamin D_3 requirements. The diet currently provided consists of high-protein pellets, fruit, vegetables, and protein items such as waxmoth larvae, locusts, egg, cat food, cheese and nuts. Gum arabic is provided for additional energy and calcium, which is particularly important for breeding females. Citrus fruits are restricted in the diet as they are potential irritants, increasing the occurrence of diarrhoea.

The diet was quantified by weighing the amount of each food item provided in each feed per group (n=8) per day. Feed remains were collected later the same day in order to calculate the amount of food that had been consumed per enclosure, and then allowing the estimation of food consumption per individual and per kilogram body mass. Control feeds were used to calculate the weight change that was due to water loss or gain. The diets were analysed for nutrient content using the Zootrition software (Wildlife Conservation Society, 1999). These nutritional compositions were then compared to requirements for New World monkeys. Zootrition was also used to analyse the composition of the food items provided to the tamarins in order to establish the nutrient levels in each food. This is useful for adjusting the diet and/or replacing food items.

The diet analysis should provide some insight into why there are health and breeding problems with pied tamarins and result in recommendations for adjusting nutrient levels. Jersey Zoo has recently produced management guidelines for pied tamarins and dietary analysis can contribute to these, in addition to the feeding practises and enrichment aspects. These are an important part of dietary management, in addition to straight nutrient composition. Nutritional studies both in captivity and in the wild are important tools in the conservation of this critically endangered primate. The contribution of the captive breeding programme can be maximised if well-balanced diets support maintenance and breeding of healthy individuals.

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DISTRIBUTION OF FOOD IN SPACE AND TIME

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In the wild, primates usually spend a large proportion of their active time foraging and feeding. Access to food and food intake are influenced by individual factors (e.g. the physiological abilities of the animal) and social factors (e.g. dominance hierarchies), and especially by the availability of food and its distribution in space and time. This paper focuses on the latter aspect.

Food resources in the wild may be scarce and widely distributed throughout the animals' home ranges, and certain food types may be available only during limited periods of the year. Ideally, feeding primates in captivity should include such a varied food distribution, both spatially and temporally.

However, the captive conditions often do not allow to realise this. Spreading out food can only be done within the limits of the animals' enclosure. Moreover, it is rarely feasible to feed more than three or four times a day, as there is not enough staff available. Also, the "zoo-day" is usually not more than eight hours long (depending on the working times of the keepers). In most zoos there is a certain degree of daily variation in foodstuffs fed, whereas a seasonal variation is more or less non-existent in captivity.

Availability and distribution of food in space and time are main factors for the regulation of food intake. Not only do they regulate the amount of food consumed within a certain time period (e.g. per day), but also influence the patterning of nutrient and energy intake during this period. It is assumed that the latter aspect is critical for an optimal (species-specific) functioning of satiation processes. Ideally, optimal feeding schedules should be developed with reference to foraging data from the field. The latter, however, are rarely available. The aim of this paper is to analyse relevant studies and to work out a tentative concept on how optimal energy and nutrient intake could look like.

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STATUS OF NUTRITION WITHIN EEP HUSBANDRY GUIDELINESS - CAN WE HELP?

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Many modern zoos have agreed to work together focussing their conservation efforts on endangered species and establishing breeding programs for these animals. In Europe these projects are called EEP's (European Endangered Breeding Programmes) and one of the responsibilities of EEP co-ordinators is to develop husbandry guidelines, aiming to achieve optimal conditions for well-being and reproduction of all the animals in the programme. An essential component of any animal's husbandry is what it should be fed and guidelines should therefore contain a section on feeding, summarising the diet consumed both in-situ and ex-situ, any special dietary requirements, handrearing protocols, nutrition-related health problems and a bibliography.

A preliminary investigation in August 2000 found that less than half of the checked EEP guidelines presented adequate advise on the nutrient requirement of the species. A questionnaire was devised with two primary aims; i) to gather up and make more widely available information on all the existing husbandry manuals and ii) stimulate their improvement by encouraging the inclusion of nutritional information in a standardised format. The questionnaire was sent to the Co-ordinator or Chair of the 125 EEPs, 32 Taxon Advisory Groups (TAGs) and 68 approved European Stud Books (ESBs) listed in the 1989/99 EEP Yearbook. Many co-ordinators have already asked for support in compiling the nutrition section of guidelines and the information collated from the questionnaire will reveal where the major gaps in nutritional knowledge lie. Plans are in progress for nutrition workshops and help sessions to be scheduled during the EAZA/EEP meeting later this year. Furthermore, Species Survival Programmes (SSPs), the North American equivalent to EEPs, are undergoing a similar review process and the results can be compared to determine areas of overlap and/or potential exchange of expertise.

Simply considering the nutrition of EEP species may ultimately have a wider impact within the zoo community. Nearly all zoos spend 3-6 % of their budget on food for their animals. The payment of more attention to the ingredients being fed could reduce this cost and improve the nutrition, mainly by simplifying the diet. Often feeding a simpler range of items will result in a better and more consistently balanced diet and ultimately, less obese zoo animals. Simplification of diets will reduce the amount of labour involved in food preparation, which may reduce expenditure but will also free up time for keepers to devote to other important aspects of animal husbandry, enrichment for example.

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MINEROL AS A MEANS OF NORMALIZATION OF BLOOD LIPID EXCHANGE IN BIRDS

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Improper nutrition due to the deficiency of certain trace elements in food is a reason of many human and animal diseases. The course and the outcome of pathological process in many respects depend on state of blood microcirculation. This circulation is responsible for receipt of substances, necessary for normal function of cells and cleaning them from slags.

The purpose of the present research is to find out the influence of multimineral component **"MINEROL"** on lipid concentrations in blood - factor, on which state of blood microcirculation mainly depends. The medical and preventive supplement **MINEROL** is a modified natural material with definite absorptive characteristics, containing more than 60 elements including (by mass): silicon, calcium, magnesium, manganese, potassium, sulfur, phosphorus, iodine, nickel, chromium, lithium, zinc, vanadium, cobalt, selenium. The influence of **MINEROL** on parameters of lipid exchange in chickens is described. There were several age groups (young and old), 20 birds of the same type in each. The following parameters of lipid exchange were studied: general cholesterol, alpha-cholesterol, beta-lipoproteins, triglycerins. The research was conducted with automatic analyzer "Express -550 " (Ciba-Corning, United Kingdom).

Application of **MINEROL** in the amount of 1 % of daily diet during two months resulted in diminution ($P < 0,01$) of general cholesterol, beta-lipoproteins, triglycerinsin in old chickens, and a downward tendency of these parameters was observed in young birds.

It is known that increased levels of investigated blood lipids lead to the hardening of arterial walls and consequently to deterioration of blood microcirculation. The diminution of these parameters with simultaneous minor increase of alpha-cholesterol parameter, which was observed after application of **MINEROL**, is evidence of a normalizing effect of this supplement.

It was also discovered that usage of **MINEROL** promotes a decrease of internal fat in organism of old birds almost in twice and actually has no influence on amount of fat in young birds.

Multimineral component **MINEROL** ensures normalization of lipid exchange in birds. It is particularly evident in case of older chickens, and gives the grounds for **MINEROL** application as hypo lipid and geroprotective means in captive birds diet in the zoos.

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NUTRITION, PHYSIOLOGICAL ADAPTATION AND RE-INTRODUCTION A CASE STUDY OF THE KNOT (*Calidris canutus*)

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The ability to adapt to changes in the environment plays an important role in the survival of species. These adaptations can take place within short time lapses, resulting in repeated physiological changes of the organism within one lifespan. The adaptation of migratory bird digestive tracks and flying muscles is an example. The ability to show these adequate changes in physiology may determine the success of individuals in a competing environment, which will be most important in re-introduction programs.

Size reduction of the knot's (Calidris canutus) digestive track takes place before the start of the migration period. At the same time the flying muscles as well as the heart muscles are increased in size. This adaptation is directed toward the effective use of energy. The trade-off between physiological capacity and environmental requirements is essential for individual as well as long term species survival.

The natural diet of the Knot consists of small shells and other organisms. The shells are found in the top sediment layer of the wetlands where they forage. This prey is swallowed as a whole. The shells are crushed using stomach muscles. This requires strong stomach muscles. Training induces the increase of the stomach musculature. Taking in larger prey incites these muscles to increase. Reduced food intake during the migration period results in reduced stomach size. During this period the Knot relies on smaller, softer shelled prey. Research showed that the food intake rate in the Knot depends on prey size and shell mass. Stomach size did not influence food intake rate. To crack larger prey specimen stronger and thus larger stomachs are required. The foraging behaviour of the Knot in-situ is adapted to this physiology.

Translating these results to the management of the Knot ex-situ, and to comparable bird species there are two major lessons to be learned. Especially so where re-introduction is a long-term option. First the willingness of the birds in captivity to accept pelleted food must not automatically lead to the use of such food. The advantage of controlled diet composition, reduced risks of diseases and such must be balanced against the possible long-term consequences of such easily digested pellets. The lack of stimulation of the stomach muscles when feeding pellets can prove to have long term lasting effects on the survival rate of the re-introduced animals. Second the increased handling time of natural food is a distinct advantage in the prevention of stereotypic behavior. Diets complemented with natural food must be considered. Providing shells hidden in a sandy substrate in a well-controlled manner is not only environmentally enriching, but also assures natural behaviour and physiological development.

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TANNINS IN THE NUTRITION OF WILD ANIMALS: A REVIEW

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The diet of many free-ranging wild animals contains significant amounts of tannins and other polyphenolics. Historically, attention has mostly focused on the negative effects of tannins on herbivores. Tannins reduce diet digestibility by impeding bacterial fermentation processes and by increasing endogenous losses; they impair the use of absorbed nutrients, can be toxic and reduce the palatability of many forages. Therefore, they act as feeding deterrants and have often been interpreted as a part of the anti-herbivore defense of plants. However, recently the antioxidant and cardioprotective potential of tannins and other polyphenolics has been emphasized in human nutrition, and polyphenolic extracts can nowadays be found amongst other human diet supplements in drug store shelves.

Wild animals in captivity are mostly fed a diet that is relatively low in tannin content. While this might suit the evolutionary adaptation of grazing species, especially the browsers could be hypothesized to face a situation where the antioxidant support from their natural forage that they have adapted to is missing in captive diets. Other positive effects have been demonstrated: Limited levels of tannins can reduce the protein degradation in the forestomach of ruminants and thereby increase the flow of more valuable amino acids to the small intestine. Tannins are effective against bacteria, fungi and viruses. Tannins are known to chelate iron in the gut and reduce its availability. In the wild, many animals therefore would have had to adapt to very low iron availabilities, whereas a captive diet would offer a relatively unrestrained iron provision. Tannins are known to prevent bloat in domestic ruminants. Tannins are effective against gastrointestinal stages of helminth parasites.

Several observations from zoological gardens can be compared to these properties. During the transition from the wild to captivity, i.e. from a natural to an artificial diet, leaf-eating Colobine monkeys suffer from gastrointestinal disorders that are associated with bloat, enteritis, and helminth infections. Bloat conditions are also observed in other leaf-eating species in captivity, like sloths or giant eland. It has been observed that some browsers are, in zoo situations, especially susceptible to parasite infections and enteritis. Some browsing species develop an iron storage disease in captivity. It is tempting to suggest the lack of tannins as an underlying common factor.

The potentially beneficial effects of a more natural dietary tannin supply for zoo animals should be further investigated.

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N-6 AND N-3 POLYUNSATURATED FATTY ACIDS IN THE NUTRITION OF WILD ANIMALS : A REVIEW

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Polyunsaturated fatty acids (PUFA) have been recognised to be vital for growth, development and health. Linoleic (LA, 18:2n-6) and alpha-linolenic (ALA, 18:3n-3) acid, the respective parent compounds of the n-6 and n-3 families, cannot be synthesised by animals and must be provided in the diet. Animals have the ability to convert these fatty acids to their respective long-chain metabolites through series of desaturation and elongation steps with variable efficiency. The main sources of LA are vegetable and seed oils, nuts, seeds and meat. In contrast, ALA is obtained primarily from green leaves, grass, seaweed and fish. When wild animals are brought into or kept in captivity, they are maintained on foods whose nutritent composition is qualitatively and quantitatively different from what they eat in their natural habitat. With regard to lipids, this nutritional practice often results in high intakes of saturated fat and low consumption of total and n-3 PUFA. This is particularly evident in zoo ungulates in which the inevitable scarcity of browse and green leaves, and thus the low provision of ALA, is manifested in abnormal tissue fatty acid patterns. Total and n-3 PUFA are reduced, and n-6 is increased. A similar shift in the fatty acid pattern of body tissues has been observed in fish, reptiles, birds, and other mammals. Given these data, it is reasonable to suspect a low n-3 PUFA status in many zoo animals. The contrast in intakes of n-3, n-6 and saturated fatty acids in captive and domestic animals as compared to their free-ranging conspecifics appears to mirror the transition in human nutrition from paleolithic conditions to modern western diets. In man, the dietary habits of ‚Western society' are associated with a high incidence of cardiovascular disease, hypertension, diabetes and some types of cancer.

Reports of clinical problems associated with n-3 deficiencies are rare in zoo animals. In man and experimental animals, insufficiency and impalance of n-6 and n-3 fatty acids leads to various clinical and sub-clinical problems including growth retardation, reproductive failure, hair loss and skin lesions, haematological disorders, impaired immune response and vascular dysfunction. A low n-3 supply might, in zoo animals, contribute to vascular disease, to skin or moulting problems, influence hibernation patterns, and aggravate cases of enterotoxemia. It might also influence fertility. Essential fatty acid deficiency has been shown to impair sperm development, egg hatchability, and fetus and newborn survival. Mammalian and avian sperm contains large proportions of PUFA, which is to a degree influenced by the dietary PUFA supply. While sperm of low fertility is often characterized by a high n-6:n-3 ratio, sperm of higher quality has higher PUFA levels and especially lowered n-6:n-3 ratios, i.e. contains more n-3 PUFA. It has been shown that the feeding of a n-3 PUFA rich diet can improve sperm quality and fertility in fowl and man. The potentially beneficial effects of a more natural dietary fatty acid supply for zoo animals should be further investigated.

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FEEDING BROWSE TO LARGE ZOO HERBIVORES: HOW MUCH IS "A LOT", HOW MUCH IS "SUFFICIENT"?

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Diet evaluations in captive browsers are often confounded by the fact that the amount of browse offered is difficult to quantify, especially if whole branches are fed. For a diet survey in captive moose (*Alces alces*), we established correlations between the diameter at point of cutting of a branch and the amount of foliage and edible twigs on it. Eight different species of trees were investigated. The correlations were allometric, and highly significant. For all tree species combined, e.g., the correlations of the total weight of a branch (y_1) and the weight of its leaves (y_2) with the diameter at point of cutting (x) were $y_1 = 0.84\ x^{1.94}$ and $y_2 = 0.48\ x^{2.48}$, respectively. Given the according equations, it was only necessary to measure the diameter of the branches fed in the institutions that participated in the diet survey. Examples are given for diet evaluations based on the estimation of edible browse derived from the equations.

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THE BOTANICAL, STRUCTURAL AND CHEMICAL COMPOSITION OF DIFFERENT PELLETED FEEDS USED IN CAPTIVE MOOSE (*Alces alces*)

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The commercially available, pelleted moose food sold under the same brand name ("Mazuri Moose Maintenance") in North America and Europe differs drastically in ingredient composition; the European formula does not contain the aspen sawdust that is regarded as the crucial ingredient in the North American diet. Apart from these feeds, other pelleted foods designed for horses, domestic ruminants and cervids are used in feeding moose in European facilities. These pelleted feeds, and for comparison grass and browse samples, were submitted to a variety of analyses in order to isolate the potentially beneficial factors of the commercial moose feeds. All pelleted feeds had comparable particle size distributions, with the North American moose feed as the notable exception, as the sawdust particles were not as finely ground as the other ingredients. All pelleted feeds were similar in nutrient composition; however, the commercial moose feeds had higher percentages of fibre, due to a higher cellulose (and in the European pellets also hemicellulose) content. The commercial moose pellets did not display significantly higher concentrations of lignin than the other pelleted feeds, in spite of the sawdust ingredient. Due to their high cellulose content, they even had lower lignin:cellulose-ratios than the other feeds and therefore rather resembled grass than browse in their fiber composition. Thus, the reported success of the commercial moose diets is most likely explained by their comparatively low energy density and high fiber content, and not by the sawdust ingredient itself. Additionally, the fact that they do not contain corn starch is considered beneficial. The use of pelleted feeds high in energy density and poor in structural fiber components is considered one of the major reasons for the nutritional problems encountered in captive moose.

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NUTRITION OF IGUANAS AT JERSEY ZOO

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Animal nutrition is a crucial aspect of maintaining and breeding endangered species in captivity. Three species of iguana were studied at Jersey Zoo, headquarters of the Durrell Wildlife Conservation Trust: rhinoceros iguana, *Cyclura cornuta cornuta* (2 adults); Lesser Antilles iguana, *Iguana delicatissima* (2 adults, 1 juvenile); and swampy iguana, *Ctenosaura bakeri* (1 adult, 4 juveniles). The aim of this study was to see if the diets were providing nutrients adequate to maintain health and allow reproduction. These animals were studied because of their endangered status, the problems that can be involved in feeding them successfully, and because *C. bakeri* was a species new to Jersey Zoo.

The diets being provided to *Cyclura* and *Iguana* consisted of forage and leafy green vegetables (such as pak choi, romaine lettuce, mibuna, chicory, pseudo-acacia and lime) grown on the organic farm at the zoo. *Ctenosaura* were also provided with chopped fruits, mealworms, crickets and locusts. The vitamin and mineral supplement Nutrobal was provided to each species. Food distribution practises promote foraging activity and provide environmental enrichment.

The diets were quantified by weighing the amounts of food provided, and calculating the amounts consumed per enclosure. Control feeds were used to correct the feed remains for weight changes due to water loss or gain. The diets were analysed in terms of the nutrients consumed per individual and per kilogram body mass, using the dietary management software "Zootrition" (Wildlife Conservation Society, 1999). The diet analyses were compared to published information on recommended nutrient levels. Zootrition was also used to analyse the composition of the food items provided to the iguanas in order to establish the nutrient levels in each food.

In general, the nutritional composition of the diets consumed was found to be satisfactory in terms of key nutrients. Fibre consumption varied from 19-29%, which exceeded the recommended minimum of 10%. Dietary fibre needs to be high to ensure gut motility and micro-organism composition in the gut. The diet of wild herbivorous iguanas contains very little fat. Fat consumption in this study varied from 2.6-3.1% for *Cyclura* and *Iguana*, and from 3.7-6.7% for *Ctenosaura*. This was expected as *Cyclura* and *Iguana* are herbivorous and *Ctenosaura* are omnivorous. Protein levels consumed by *Cyclura* were higher than the recommended 10-20% protein for this species. *Iguana* consumed 22% protein, within the requirement boundaries of 15-30%. The protein consumption of *Ctenosaura* appeared to vary with age: the adult consumed 20% protein, whereas average juvenile consumption was 26%. The calcium to phosphorus ratios of the *Cyclura* and *Iguana* diets exceeded the recommended 2:1, before taking Nutrobal into consideration, but *Ctenosaura* required Ca supplementation to increase the Ca:P ratio to 2:1, to compensate for the inverse Ca:P of insects and the low calcium content of fruit.

Produce from the organic farm at Jersey Zoo appears to be contributing to well balanced diets for the iguanas, in terms of nutrients required to maintain health and allow reproduction, as demonstrated by the hatching in November 2000 of a complete clutch of *I. delicatissima* eggs.

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BODY PARTITIONING OF PROTEIN AND SULPHUR AMINO ACIDS IN THE NORTH AMERICAN PORCUPINE (*Erithizon dorsatum*).

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The porcupine (*Erethizon dorsatum*) is a large herbivorous arboreal rodent widely distributed across the North American continent. Its most prominent feature is the quills primarily located on the back and tail which serve as a defence against predators. In addition, hair grows between the quills in preparation for winter and also covers the ventral surface and limbs of the animal. The plant-based diet of the porcupine, particularly the winter food supply, is relatively low in protein and the digestibility of this protein is low. The high sulphur amino acid (SAA) content of the protein of quills and hair makes these a potentially limiting nutrient in the porcupines diet, therefore. This study was designed to determine the relative proportions of SAA in the quills and hair and the remainder of the body of road-killed porcupines collected in the late fall season. Six animals were used in the study (mean body weight (BW) 6.79 $\pm$ 0.51 kg). All quills and hair were removed from the dorsal surface by manual plucking. The shorter hair on the face, limbs and ventral surface was removed with electric clippers. Quills and hair for a given carcass were combined, chopped into short lengths and force air dried to constant weight before grinding 3 times through a 0.6 cm plate. The remainder of each carcass was emptied of stomach and cecum contents, frozen, sliced and ground through a 0.6 cm plate. Subsamples were freeze dried and reground through a 0.6 cm plate for further analysis. Analytical dry matter (DM) and crude protein (CP) were measured on quill/hair and body samples and SAA content estimated from literature values. Total body DM was 1.80 $\pm$ 0.14 kg, of which 0.46 $\pm$ 0.03 kg was quills/hair, representing 26% of total DM. CP and estimated SAA were 1.14 $\pm$ 0.12 kg and 65.3 $\pm$ 5.4 g respectively for the whole body and 0.45 $\pm$ 0.03 kg and 45.9 $\pm$ 3.3 g for quills/hair. Thus quills/hair represented 40% of total body CP and 71% of total SAA. The disproportionate demand for SAA for quill/hair growth implies a significant allocation of a limited nutrient resource to defensive purposes and suggests that SAA may be a limiting factor for growth in porcupines, particularly in the postweaning period when a plant-based diet is consumed.

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A NUTRITIONAL REVIEW OF THE DIET FED TO THE ST. LUCIA AMAZON *Amazona versicolor* AT JERSEY ZOO

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The St. Lucia amazon, *Amazona versicolor,* has been kept at the Jersey Zoo, headquarters of the Durrell Wildlife Conservation Trust, for 24 years. In the initial stages of the breeding programme, problems were encountered with the health of the birds and therefore reproductive output was compromised. High mortality in both wild-caught adults and captive-born youngsters, of nutrition related diseases, prompted an investigation into the diet fed to the parrots held at the Trust. Preliminary feeding trials established the nutritional content of the diet offered, and highlighted areas where improvement was needed. Modifications were implemented, thus forming a diet that was believed to be more suited to the nutritional requirements of the birds. In the years following the diet modifications there was a significant improvement in the overall health of the parrots and a burst of reproductive activity. However, poor fertility has blighted the breeding programme, and with the death of a mature, wild-caught breeding male in 2000 attributed to visceral gout (the bird was also obese), the diet of *A. versicolor* has once again come under scrutiny. The current diet offered and consumed was examined by weighing food items provided and left over and analysed using nutritional analysis software (Zootrition, Wildlife Conservation Society, 1999) and was compared to the requirements for a psittacine diet by Baer and Ullrey (1986) to assess the quality. To establish how much "drift" had occurred in the diet offered since the original modifications in 1992, comparison was also made between the current diet and the diet listed for the St. Lucia parrot in the Dietary Manual of the Jersey Wildlife Preservation Trust (1995). The results suggested that crude protein levels were high, vitamin E and manganese were low, and that dietary calcium was deficient, a problem intensified by the high levels of phosphorus. Fat levels were slightly high and should also be monitored. Further investigation is needed to establish the most effective way of adjusting the diet. The comparison between the current diet and the diet in use in 1995 revealed that some changes have occurred in the amount offered of certain food items. In the process of re-balancing the diet, these changes will be taken into consideration to see if they can account for some of the nutritional imbalance in the current diet.

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EVOLUTION OF A BROWSE DATABASE - A GLOBAL APPLICATION.

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Browse - the new "buzzword" within zoological communities. Browse can include shrubs, trees, woody vines and stems, including various plant parts like berries and flowers. Browse is used for nutrient supplementation, behavioral enrichment and for some animal species it is life. Browse can also mean death to animals if a wrong plant or part is fed. With all of these parameters - good and bad - browse nutritive and management information has been collected on browse species known to "nurture" and "protect" animal collections. Browse databases have been compiled within zoological institutions throughout the United States, Europe, and countries worldwide. Information entered into a database usually centers around a "specific" country or region. Since plants grow better in some climates than others, it is difficult to use database information universally. Formats that would allow global application in browse utilization are critical. Landscape and seed industries recommend plantings based on plant hardiness. Plant hardiness is an index based on minimum temperatures and could be applied universally. For example, in the United States, plant hardiness zones range from 2 to 10, while in Europe they range from 5 to 10. A plant hardiness zone of 5 would include minimum temperatures of -20° to -10° F or -29.0° to - 23.5° C. Plant hardiness information is readily accessible on the Internet, and this index could be used to "begin" the process of developing a global browse database. It needs to be emphasized that there are many other variables involved in plant growth and resulting nutritive value of browse -humidity and rain fall, soil type, altitude and others. Plant hardiness is not the whole answer, but it is a first step in the development of a database that would allow entry of browse information for global application. Long-term goals for the browse database will be to incorporate it into the Global Food Composition Database proposed by the Conservation Breeding Specialist Group (CBSG) Working Group. The browse section of this Global Database will focus on identified variables utilizing current information technology. Fields to be incorporated into an Internet-accessible, intuitive-search database of browse samples include (minimally): Taxonomy; Phenological characteristics; Plant part(s); Growth Characteristics; Geographic Information and Abiotic Information including GPS coordinates (with a hyperlink to mapping capability); Source (i.e. natural vs. cultivated); Date of Collection; List(s) of Consumer Species; Nutrient Data; Bibliographical References; and Links to other existent Databases (i.e. Medicinal, Toxicological, Human Food, Water Quality). Specific details to be considered under these various fields will be discussed, along with implications for impacting and assessing nutrient quality of browse. Through creation of linked global databases with multi-users and contributors, we can begin to identify and fill knowledge gaps to allow us to better understand and meet the nutritional needs of animal species under our care.

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RICKETS IN JUVENILE MORELET'S CROCODILE (*Crocodylus moreletti)*

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The Morelet's crocodile is a relatively little known species from the Atlantic coast of Mexico and northern Central America. It`s length rarely exceeds 3 m and has it has a characteristic broad snout. These animals live primarily in freshwater habitats, particularly marshes, swamps, ponds and lagoons, but in some areas this species can be found in brackish water areas. They are seldomly held in zoos and scientifical data including nutritional requirements are scarce.

Calcium and phosphorus are very important minerals in reptile nutrition, but many diets in zoos are still not sufficiently balanced. To achieve optimal growth, including a healthy skeleton, a well-balanced supply with these minerals and also vitamin D is the prerequisite. The present case report is intended to share our experiences.

In Nürnberg Zoo, three Morelet's crocodiles hatched for the first time in a european zoo in December 1999. The animals had an average weight of 31.9 g. They had access to artificial UV light. The dietary management prooved to be difficult. Firstly feeding recommendations are rarely found in the literature and secondly it was a challenge to feed anything at all to the freshly hatched crocodiles. The diet constisted of crickets and once or twice a week of baby mice. No supplementation was given. Occasionaly the animals received chicks and fresh meat strips. After 3 ½ months with an average body weight of 125.8 g, the animals were x-rayed, because one had a broken leg. Radiography revealed severe signs of rickets in all three animals. The animal with the fracture was treated with a T-buster-splint bandage. In addition, the diet was enriched with mineral and vitamin supplements. After 6 weeks radiography revealed a healed fracture and physiological ossification in all animals. The crocodiles had an average length of 528.3 mm and a weight of 445.3 g.

Previous studies described that Ca and P play an important role in the nutrition of reptiles (Allen, 1989; Allen et al., 1993). It is very important for growing animals to give them enough vitamin D and calcium with a Ca:P ratio of a least 1:1. From the literature it is known that crickets have a calcium content of 0.47 % and a Ca:P ratio of 0.49 (Dennert, 1997). Recommendations for other reptiles are (much) higher (Donoghue and Langenberg, 1994). Nevertheless crickets prooved to be the most appropriate food for our animals. In their natural habitat growing Morelet's crocodiles also eat insects, as well as small fish, and worms. Considering the small size of the young reptiles, crickets also fulfil practical feeding purposes.

In conclusion this case report demonstrates a quick recovery of crocodiles with rickets following diet supplementation with minerals and vitamins. Mineral requirements of juvenile Morelet's crocodiles appear to be comparable to other reptiles. A diet consisting of crickets with or without a combination with meat always requires supplementation since the Ca content and the Ca:P ratio are too low.

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FAECAL ANALYSES: A TOOL TO DETERMINE DIET SELECTION/COMPOSITION OF UNGULATES IN-SITU/EX-SITU.

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The diets of wild ungulates are related to the cover of the vegetation they feed on in their natural habitats. Ungulates in captivity can not be fed on their original natural resources. Discussions on the composition of diets for captive animals to ensure that their health, welfare and reproduction are not damaged by poorly or wrongly compiled diets are going on to date. The trend to provide captive animals with natural surroundings in Zoos should also include a diet as natural as possible. Ex-situ ungulate species management can make use of the results in-situ research techniques.

In Lake Nakuru National Park situated in the Rift Valley Province of Kenya, research is done combining feeding behaviour studies and the technique of faecal analyses to confirm the actual food consumed and digested by different ungulates species grazing and/or browsing in their natural environment. Results from this type of research contribute to the composition of natural diets for ungulate species in captivity. The purpose of faecal analyses is to identify plant/grass-species and to measure the abundance of these species as a percentage of the total faecal contents of a specific collected dung sample. Related to habitat vegetation composition this provides useful data on diet composition for ex-situ ungulate species management. The technique of faecal analyses and its use is presented, based on an example of research on faecal analyses on two competing ungulate species in Lake Nakuru National Park, the African Buffalo (*Syncerus caffer*) and the Defassa Waterbuck (*Kobus ellipsiprymnus*).

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INVESTIGATIONS ON THE USE OF CHROMIUM OXIDE AS AN INERT, EXTERNAL MARKER IN CAPTIVE ASIAN ELEPHANTS (*Elephas maximus*): PASSAGE AND RECOVERY RATES

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Digestibility studies in zoo herbivores that are kept in groups are often confounded by the fact that the intake of hay, which is usually offered to the whole group, cannot be measured on an individual basis. This problem can be solved by using a double marker method with an internal and an external marker. In elephants, the internal marker lignin has repeatedly been used successfully; however, no external digestibility marker has been reliably established for this species.

Seven captive Asian elephants were fed 500 g of chromium oxide per animal as a pulse-dose. Faeces were collected in toto for 60 hours afterwards. The amount of faeces from each single defecation was weighed, and a representative subsample was taken for chromium analysis. All faeces defecated during night hours were treated as a single defecation unit. With the individual chromium concentrations and the total weights, the recoveries of the chromium marker could be calculated, and the passage rates for these animals were determined. Additionally, four animals in an elephant orphanage in Sri Lanka were fed the same amount of chromium oxide. For these animals, only the passage rates could be determined.

The average first marker appearance was 24 hours, and the average last marker excretion 54 hours after marker feeding. On average, the elephants excreted 3.9 kg faeces/100 kg of body mass and day. The average chromium oxide recovery was 97 %.

The results confirm that chromium oxide is a reliable external digestibility marker in Asian elephants. The passage rate data compares well with other data from the literature. Like other perossidactyls, the elephant uses the digestive strategy of passing large amounts of low quality forage through its gut within a short period of time.

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VISITOR'S VIEWS ON BROWSE USE IN CAPTIVE GORILLA AND GIRAFFE DIETS

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As part of a more comprehensive study which aims to get more insight into the nutritional value of browse in zoo diets, interviews were conducted with staff responsible for zoo nutrition in 10 Dutch zoos. Almost all respondents indicated that they experienced the following problems with browse: irregular availability, lack of reliable nutritional data and storage problems. Respondents also indicated that they would like to get more insight in the possibilities to replace browse in the present rations. (Kool and Smit, 2000)

The obvious approach towards replacing food items in a diet is to look for products with comparable nutritional properties and suitability as environmental enrichment. However in a zoo setting it is possible that there are also other factors which play a role. One of these possible factors is the public's attitude towards the feeding of the animals and the food items used. On three different days a total of 300 Rotterdam Zoo visitors were interviewed on the subject gorilla and giraffe feeding. Knowledge of facts about the feeding of these animals was explored by asking respondents thirty questions about the necessity of ration components, the animal's feeding behaviour and the specific function of certain diet components. Furthermore eight questions were asked to find out how important the visible availability of browse in animal enclosures is for zoo visitors.

Results showed no significant differences in knowledge about gorilla and giraffe feeding between year cardholders and other visitors. Only 24 % of the respondents thought that banana's are not a necessary item in gorilla diets. When the same question was asked about fruit in general only 6 % expressed the view that this is not a necessary component in Gorilla diets. Slightly more then 60% of the visitors thought gorillas need branches and leaves in their diet. Only 17% considered concentrate as a necessary diet component.

More than 75 % of the respondents stated that branches are necessary for playing behaviour. About 60 % of the respondents thought that browse is important for teeth cleaning. Fruit is a necessary component for giraffes according to 37% of the visitors. For vegetables this figure is 46 %. Over 75% expressed the view that both hay and leaves are an important diet component. Only 35% of the respondents agreed upon the statement: " The digestive system of the giraffe is similar to the digestive system of cattle".

A majority of the visitors (56%) stated that they would find the animal enclosures less attractive when no browse would be fed. Thirty four percent indicated that this would seriously affect their pleasure in visiting the zoo. Although this study had an indicative character, results show that it could be worthwhile to put effort in educating the public on the background of choices made in the composition of zoo diets. Visitors do not only enjoy a zoo visit because of the animals but also because of the environment the animals are exhibited in. This study indicates that the diet offered is an important part of this environment for the visitors.

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FEEDING ALDABRAN GIANT TORTOISES (*Dipsochelys* SPP) IN CAPTIVITY

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Aldabran giant tortoises (Dipsochelys spp) are kept in over hundred zoos and institutions around the world. Many of these animals live there already for decades. Despite this, surprisingly little is known about the exact nutritional requirements of these animals. However there is certainly a need for more knowledge on this subject since quite a few institutions reported possible nutrition related disorders like geophagy, muscle weakness, loose stools, constipation and carapace inflammation.

To obtain more insight in the current status of captive Aldabran spp nutrition, a survey was conducted among zoos, which were known to keep these animals. Questionnaires were sent to almost 100 zoos and institutions. The respondents were asked to answer general questions about the animals and their husbandry, diet composition, general health status, UV-lighting regime and possible nutrition related disorders.

Over 30 % of the questionnaires were returned. The information presented in the returned forms was used to calculate the nutritional content of the diets fed with the help of various food tables and compared against data on the in situ food intake found in literature. Preliminary results show a considerable spread in diets offered (i.e. predominantly domesticated fruit and vegetables or predominantly grass, hay and other roughage's.) and nutritional content. Possible implications of this in connection with reported nutritional disorders will be discussed. All obtained data will furthermore be used to present an overview of the current state of captive Aldabran spp. nutrition.

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IMPORTANCE OF BROWSE IN DUTCH ZOO DIETS

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Browse (branches, twigs and leaves of woody plant species) are an important component of many zoo diets in The Netherlands. However not much data is available on the actual use of this type of feed nor on its specific nutritional and other properties. To compile an inventory of the current use of browse in Dutch zoos and to get more insight in possible problems related to the feeding of these products 10 zoos were visited and in each zoo an extensive interview took place with the person responsible for zoo nutrition.

In the 10 zoos a total of 29 (browse) plant genera are used in the various diets. Three plant genera (oak (Quercus spp), willow (Salix spp) and birch (Betula spp.)) were used in all zoos. Ten plant genera are used as browse in only one zoo. It is remarkable that only one respondent claimed to be able to identify the browse used on species level. Most of the browse is collected on the zoo's premises itself or it's near surroundings. Browse is occasionally also obtained from the municipal botanical department. Only three zoos buy some of the required browse regularly.

Browse conserving is not practised often. This implies that most of the browse is fed during late spring, summer and early autumn which implies that rations differ between seasons. Where conserving takes place, freezing is the most important method. A few zoos reported that they have attempted to dry browse but due to climatic conditions and/or lack of experience with this process this proved to be rather unsuccessful.

Reasons mentioned for feeding browse were: its palatability, use as environmental enrichment and its nutritional value. Although all respondents stated the nutritional value as an important reason to feed browse, the composition of the browse was determined in only one zoo by sending it to a laboratory. Two zoos indicated that (estimated) nutritional values of browse were used in diet calculation. Eight zoos stated that they would like to have more information on nutritional values of browse or its possible alternatives.

Most zoos have a preference for willow spp. as browse. This preference is not based on any knowledge of the nutritional composition of willow but mainly on the (assumed) positive experience of other zoos and its availability. Also its palatability is an important aspect. In connection with browse the respondents mentioned the following problems: lack of (regular) availability, insufficient and inadequate storage facilities and lack of nutritional data. Six or more of the zoos indicated to be interested in the results of research on the following subjects: nutritional composition of browse (10/10), the possibilities to replace browse by other products (9/10), factors influencing the nutritional composition (7/10), effects of secondary plant components (7/10), browse as an indispensable component of the rations (6/10).

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REINDEER FEEDING IN RANUA ZOO

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Ranua Zoo is located very far in north (just 80 km south of the Arctic Circle), so we work in an area where the reindeers also live in wild. Actually the reindeers are not wild animals, but they spent most of their life in wild, up in north most of the year, but in this area the keepers take most of the animals in enclosures for the coldest part of winter (from January to April). In the whole Finnish Lapland we have about 200 000 reindeers (and 200 000 people, so everybody has one reindeer!) and they produce 2 000 000 kg of reindeer meat every year. In many zoos people have had problems in feeding captive reindeers, but here up in north its not a problem. In wild the reindeers have big seasonal changes in their nutrition. The metabolic level is in winter 45% lower than in summer. Also the plants they eat are very different in winter and in summer. In summer they use green plants; grass, many different species of plants, leaves of trees (*Betula*, *Sorbus* and *Salix* species). In winter they prefer lichens (*Cladonia* and *Cladine* species) and also arboreal lichen. In southern Lapland they also eat *Dechampsia flexuosa* and some other grass and brushwood (*Vaccinium* and *Erica*). Whenever possible, the lichens make even 50-60% of the food in winter. Nowadays in many areas there is no longer enough lichen available. Thus in many areas the keepers also use pellets for feeding the reindeer in wintertime in addition to dry hay and dried leaves. In our zoo we try to follow the seasonal changes as much as possible. In summer we feed the reindeers with green grass and green leaves. They also get some pellets - the idea being that they are allowed to eat as much as they want. In autumn they eat lots of mushrooms in wild and so we offer mushrooms also for our animals. They also get vegetables or fruits in September/October. When the winter starts and snow comes, the reindeer start to get lichens and the winter diet includes pellets, lichen, dried hay and leaves. So in winter the diet is of much poorer nutritional quality than in summer. One important thing is to take care of the parasite-problem. The reindeers are very sensitive to parasites, so the medical care of parasites throughout the year is important.

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NUTRITIONAL DISORDERS OF THE SKELETON IN EMUS AND RHEAS

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Keeping of emus (*Dromaius novaehollandiae*) and rheas (*Rhea americana*) under european environmental conditions is discussed frequently. The local climate and available areas for grazing and moving activities don´t favour the keeping of such birds originated from South America (rhea) or Australia (emu) under local conditions. Furthermore there are risks for animals´ well-being due to the lack of experiences as well as due to the fact that species-specific complete diets are not available continuously. Therefore home-mixed diets are fed, that are often unbalanced and leads occasionally to nutritional disorders of skeleton. In the following case reports those problems caused by faults in feeding and mineral supply are described.

Case 1:
Due to a supply shortage an owner of a small zoo fed emus a home-mixed diet (ingredients: pelleted diets for piglets as well as for rabbits, mineral product rich in protein, $CaCO_3$). The hatched emu chickens could be adapted very quickly to this diet and showed high growth rates in the first weeks of life. In the age of 3 to 4 weeks 13 of 37 chickens showed a reluctance to rise or move. One week later these chickens showed ataxic moving activities as well as slight thickening of the distal tibiotarsus and proximal tarsometatarsus, that increased in the following 14 days. At the same time the long bones developed rotational deformities (bones turned outwards and caused a „paddling movement“).

Nutritional history: In a critical examination of mangers a macroscopic difference between the offered feed (pelleted) and the refusals (white-grey fines) could be observed. Crude fiber and starch of the refusals were lower, but crude ash and calcium contents were higher compared to offered ration. Data of blood chemistry showed slightly lower mineral contents and X-rays underlined the bad posture of the legs.

Assessment: Due to the different prepared feedstuffs of the home-mixed ration (pelleted as well as meal) the ingredients of the diet could not be mixed well, so the emus could preferred the pelleted components (Ca-content in the real intake lower than in the offer; furthermore a protein content of 22% was measured) and refused the mineral supplement. This selective ingesting behaviour, the high growth rate of emu chickens and the insufficient mineralization of skeleton encourages the occurence of the observed clinical signs (perosis).

Case 2:
3 of 15 young rheas (3 months) showed unphysiological postures of the necks vertebral column. The „diet“ was based on corn, pelleted alfalfa, apples, lettuce and white bread in the first 8 weeks of life; afterwards a pelleted complete diet was fed.

Clinical history: The X-ray of vertebral column showed complete healed up fractures of individual vertebrae.

Nutritional history: Before feeding the complete diet the owner observed a selective ingesting of corn and white bread, whereas the other components were refused. The preferred components are characterized by low mineral contents (especially calcium, copper).

Assessment: Due to an insufficient mineralization of the skeleton and a high mechanical stress (rough handling to applicate a deworming) fractures of the vertebral column occurred. After feeding the complete diet these fractures healed up due to the better mineral supply of the ingested commercial complete diet.

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THE DIET AND FEED ADJUSTMENT FOR UNGULATES AT THE TAIPEI ZOO

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Currently the Taipei City Zoo raises 377 types of ungulates, in 11 families, and 44 species. From 1997 on, we adjusted the types of feed and formulations, which began with fresh forage and edible hay. Included were six kinds of fresh grass, branches, and leaves. These are used for the major food for our ungulates, which effectively reduces the undesirable condition of soft excrement, which is often seen with our giraffes before. We experimented with five kinds of imported hay between 1997 and 1999, eventually eliminating all but one type exclusively; the domestically produced Pangola hays ad libitum since October 1999. In light of the damp weather (Monsoon season) at Taipei, especially in wintertime, the hay storehouse is air-conditioned and kept at the constant temperature of 16~18°C. Two dehumidifiers are kept on all day to control the relative humidity under 75%.

We also increase different alfalfa elements in the feed and bring the content of vitamin E in compound feed from 100 IU/kg to 400 IU/kg. In the instance of our local Formosan serow, we started to increase the supply of compound feed and vitamin E additive to their diet in 1997, and improved the feeding method of branches and leaves. Consequently, there are less episodes of diarrhoea and higher survival rates of young animals in the winter. The serow at the zoo multiplied from 4 in 1997 to 11 in 2000. The numbers of ungulates at the zoo are more than three hundred, so we attempted in May 2000 to add antihelminthic (flubendazole) in the compound pellet feed for parasite control. Numerous *Ascaris* were purged from our Mongolian wild horses and zebras only one day after administration. The same method (Ivermectin 0.2mg/kg body weight) was used to purge nematode in October 2000, which also provided good effects. In the future as part of our parasite control efforts we will add suitable doses of antihelminthic in the compound feed pellets to address the specific need of certain species.

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